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Society
FOR THE
Promotion of Engineering Education

PROCEEDINGS
OF THE
TWENTY-SECOND ANNUAL MEETING
HELD IN
PRINCETON, N. J., JUNE 23 TO 26, 1914

Volume XXII

EDITED BY
ANSON MARSTON
FREDERIC L. BISHOP
HENRY H. NORRIS

PITTSBURGH, PA.
OFFICE OF THE SECRETARY
1915

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

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* Deceased.

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* Deceased.

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FRED. P. SPALDING, 1904–6,
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MILO S. KETCHUM, 1904–6,
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C. L. Mees,
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R. S. Woodward.
Mansfield Merriman.
Cady Staley,

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* Deceased.

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Arthur Beardsley,
Robert Fletcher,
John Galbraith,*
William Kent,
T. C. Mendenhall,
W. H. Schuerman,
M. E. Wadsworth.

Terms of Office Expired in 1900.

Storm Bull,*
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Albert Kingsbury,
F. O. Marvin,*
R. B. Owens,
R. L. Sackett,
R. H. Thurston.*

Terms of Office Expired in 1901.

T. N. Drown,*
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I. N. Hollis,
Gaetano Lanza,
P. C. Ricketts,
R. G. Thomas,
C. M. Woodward.*

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J. J. Flather,
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F. W. McNair,
J. M. Porter,
A. J. Wood.

Terms of Office Expired in 1903.

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D. C. Jackson,
N. C. Ricker,
J. P. Brooks,
Edgar Marburg,
A. L. Williston,
J. C. Nagle.

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D. C. Humphreys,
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W. G. Raymond,
L. E. Reber,
L. S. Randolph.

Terms of Office Expired in 1905.

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L. J. Johnson,
W. M. Towle,
H. S. Jacoby,
Elwood Mead,
J. L. Van Ornum,
Edward Orton, Jr.

Terms of Office Expired in 1906.

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Henry W. Spangler,*
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Terms of Office Expired in 1907.

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Terms of Office Expired in 1908.

Victor C. Alderson,
Arthur H. Ford,
H. P. Talbot.
Francis C. Caldwell,
Henry S. Munroe,
A. L. Williston,
Frederick W. Sperr.

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* Deceased.

Terms of Office Expired in 1909.

Charles F. Burgess,
Arthur M. Greene, Jr.,
John F. Hayford,
Milo S. Ketchum,
Henry H. Norris.
Thomas W. Palmer.
Joseph A. Thaler.

Terms of Office Expired in 1910.

Fred W. Atkinson,
Mortimer E. Cooley,
Walter B. Russell,
William Kent,
Harold B. Smith.
William S. Franklin,
Charles F. Scott,

Terms of Office Expired in 1911.

Lester P. Breckenridge,
Thomas Gray,*
Lewis J. Johnson,
William T. Magruder,
Clarence A. Waldo.
William G. Raymond,
Herman Schneider,

Terms of Office Expired in 1912.

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A. J. Wood,

---

* Deceased.

DECEASED MEMBERS.

Name.	Year of Election.	Date of Death.	Memoir. Vol. Page.
C. L. Adams	1904	Sept. 16, 1914.	XXII, 414
Philip R. Alger	1909	February 23, 1912.	XX, Part II, 491
William A. Anthony	1907	May 29, 1908.	XVI, 409
George W. Atherton	1904	July 24, 1906.	XIV, 292
Warren Babcock	1908	May, 1913.	XXI, 434
Volney G. Barbour	1894	June 4, 1901.	IX, 340
Charles B. Brush	1893	June 3, 1897.	VII, 181
Storm Bull	1893	November 18, 1907.	XVI, 407
Octave Chanute	1907	November 23, 1910.	XIX, 501
S. B. Charters, Jr.	1911	December 29, 1912.	XX, Part II, 493
S. B. Christy	1893	Nov. 30, 1914.	XXII, 415
Eckley B. Coxe	1894	May 13, 1895.	VII, 182
Chas. S. Denison	1893	July 31, 1913.	XXII, 411
Thomas M. Drown	1895	November 16, 1904.	XII, 244
Chas. B. Dudley	1894	December 21, 1909.	XVIII, 446
Francis R. Fava, Jr.	1894	March 28, 1896.	VII, 183
A. J. Frith	1911	November 10, 1913.	XXI, 435
Estevan A. Fuertes	1894	January 16, 1903.	XI, 372
Henry Fulton	1894	December 6, 1901.	X, 258
John Galbraith	1893	July 22, 1914.	XXII, 410
Thomas Gray	1895	December 19, 1908.	XVII, 238
Wm. F. Gurley	1913	February 17, 1915.	XXII, 417
Herbert G. Greer	1894	March 7, 1900.	VIII, 371
Lyman Hall	1904	August 16, 1905.	XIV, 287
E. L. Hancock	1903	October 1, 1911.	XIX, 505
Albert H. Heller	1903	February 20, 1906.	XIV, 290
H. R. Huelle	1914		
John B. Johnson	1893	June 23, 1902.	X, 259
J. W. Johnson	1907	August 29, 1911.	XIX, 506
Rodney G. Kimball	1894	April 25, 1900.	X, 261
Burton S. Lanphear	1897	October 14, 1904.	XII, 249
Benjamin F. La Rue	1899	December 22, 1903.	XII, 243
N. W. Lord	1907	May 23, 1911.	XIX, 507
C. S. Magowan	1896	November 14, 1907.	XVI, 406
F. O. Marvin	1893	Feb. 11, 1915.	XXII, 416
Charles P. Matthews	1898	November 23, 1907.	XVI, 408
J. D. Newton	1908	August 8, 1912.	XX, Part II, 490

Name.	Year of Election	Date of Death.	Memoir. Vol. Page.
T. M. Phetteplace.....	1903....	September, 7, 1913.	XXI, 436
S. W. Robinson........	1893....	October 31, 1910.	XIX, 510
J. D. Schuyler........	1910....	September 13, 1912.	XX, Part II, 494
Justus M. Silliman...	1894....	April 15, 1896.	VII, 184
T. Guilford Smith.....	1911....	February 20, 1912.	XX, Part II, 492
H. W. Spangler........	1893....	March 17, 1912.	XX, Part II, 488
James H. Stanwood....	1894....	May 24, 1896.	VII, 185
F. H. Stillman........	1911....	February 18, 1912.	XX, Part II, 490
Jos. E. Stubbs.........	1897....	May 27, 1914.	XXII, 412
Fred. W. Taylor	1912....	March 21, 1915.	XXII, 413
Robert H. Thurston...	1893....	October 25, 1903.	XII, 246
Alphonse N. Van Daell.	1897....	March 28, 1899.	VII, 186
J. A. Veazey..........	1911....	August 21, 1911.	XIX, 512
John R. Wagner.......	1894....	January 21, 1899.	VII, 187
Francis A. Walker....	1896....	January 5, 1897.	VII, 188
Howard S. Webb.......	1897....	June 12, 1905.	XIV, 286
Nelson O. Whitney....	1893....	March 17, 1901.	IX, 339
James R. Willett......	1896....	May 9, 1907.	XV, 679
De Volson Wood......	1893....	June 27, 1897.	V, 325
Calvin M. Woodward...	1894....	January 12, 1914.	XXI, 437

GENERAL SUMMARY OF MEMBERSHIP.

March 15, 1915.

Institutions Represented.	
Colleges and Universities Teaching Engineering.	
Domestic	145
Foreign	18
Manual, High, Correspondence and Trade Schools	25
Total Institutions	188
Institutional Members	48
Members	1,381
Total Members	1,429

GROWTH OF MEMBERSHIP.*

Aug.	20, 1894	156	
Sept.	2, 1895	184	
Aug.	20, 1896	200	(about)
Aug.	16, 1897	203	
Aug.	18, 1898	226	
Aug.	17, 1899	238	
July	2, 1900	249	
June	29, 1901	261	
June	27, 1902	253	
July	1, 1903	271	
Sept.	1, 1904	325	
June	28, 1905	379	
July	2, 1906	400	
July	1, 1907	415	
June	27, 1908	675	
June	24, 1909	759	
June,	23, 1910	848	
June	27, 1911	1,071	
June	1912	1,102	
June,	1913	1,158	
March,	1914	1,291	Institutional members.......48
March,	1915	1,381	Institutional members.......48

* These figures are taken from the reports of the Secretary, presented at the annual meetings, except the figures for 1914 and 1915, which were taken from the corresponding year book.

SUMMARY OF MEMBERSHIP BY OCCUPATIONS.

	Teachers	Non-Teachers
Administrative Officers in Industrial, Constructing and Operating Companies	—	84
Architecture	12	7
Deans and Directors only	—	41
Deans and Directors also holding professorships	94	—
Drawing	67	1
Engineering:		
Agricultural	10	2
Ceramic	1	1
Chemical	7	6
Civil	191	60
Electrical	177	61
Experimental	20	—
Gas	14	7
General	18	33
Highway	20	10
Hydraulic	38	—
Industrial and Efficiency	12	12
Irrigation	—	9
Marine	1	—
Mechanical	168	38
Mining	21	1
Municipal, State and Sanitary	19	11
Publicity	—	2
Railway	31	14
Steam	35	10
Structural and Bridge	39	28
Topographic and Geodetic	6	1
English and other Languages	12	—
History and Economics	2	3
Journalists, Librarians and Publishers	—	24
Machine Design	43	6
Manual Training	9	—
Mathematics	111	—
Mechanics and Materials	81	4
Officers of National Societies	—	12
Petrography and Mining Geology	—	1

	Teacher	Non-Teacher
Presidents and other Officers of Eduucational and Allied Institutions	—	50
Science:		
Chemistry	20	3
Geology	7	4
Metallurgy	10	—
Physics	72	3
Shops and Mechanic Arts	52	—
Trustees of Educational Institutions	—	11
Consulting Engineers	—	42
Various other Occupations	—	33

GEOGRAPHICAL DISTRIBUTION OF MEMBERSHIP.

Alabama	14	Mississippi	8	Virginia	14
Arizona	2	Missouri	39	Washington	21
Arkansas	7	Montana	7	West Virginia	8
California	26	Nebraska	13	Wisconsin	36
Colorado	33	Nevada	4	Wyoming	3
Connecticut	26	New Hampshire	7	Australia	6
Delaware	5	New Jersey	39	Belgium	1
Dist. of Columbia	11	New Mexico	6	Brazil	3
Florida	6	New York	170	Canada	36
Georgia	4	North Carolina	10	Chile	3
Idaho	5	North Dakota	8	China	4
Illinois	95	Ohio	85	Cuba	1
Indiana	27	Oklahoma	10	England	2
Iowa	35	Oregon	10	Greece	1
Kansas	36	Pennsylvania	172	Hawaii Territory	2
Kentucky	4	Rhode Island	12	Hungary	1
Louisiana	10	South Carolina	7	India	4
Maine	8	South Dakota	6	Japan	3
Maryland	9	Tennessee	7	Mexico	1
Massachusetts	118	Texas	21	Norway	1
Michigan	49	Utah	9	Panama	1
Minnesota	37	Vermont	10	Turkey	2
				Total	1381

INSTITUTIONS REPRESENTED IN INDIVIDUAL MEMBERSHIP.

	1912	1913	1914
Acadia University, Wolfville, Nova Scotia	1	0	0
Akron, Municipal University of, Akron, O.	0	0	2
Alabama Polytechnic Institute, Auburn, Ala.	8	8	8
Alabama, University of, University, Ala.	3	5	5
Alberta, University of, Edmonton South, Alta, Canada	1	1	2
Alexander Hamilton Institute, New York, N. Y.	0	1	1
Arizona, University of, Tucson, Ariz.	1	2	2
Arkansas, University of, Fayetteville, Ark.	4	5	6
Armour Institute of Technology, Chicago, Ill.	5	5	6
Boston Industrial School for Boys, Boston, Mass.	2	2	2
Bradley Polytechnic Institute, Peoria, Ill.	2	2	2
Brooklyn Manual Training H. S., Brooklyn, N. Y.	1	1	1
Brooklyn Polytechnic Institute, Brooklyn, N. Y.	7	7	8
Brown University, Providence, R. I.	9	9	9
Bucknell University, Lewisburg, Pa.	2	2	2
Buffalo Technical H. S., Buffalo, N. Y.	1	1	0
California, University of, Berkeley, Cal.	6	7	4
Carnegie Institution, Washington, D. C.	1	1	1
Carnegie Institute of Technology, Pittsburgh, Pa.	13	11	14
Case School of Applied Science, Cleveland, O.	14	17	17
Chestnut Hill Academy, Chestnut Hill, Pa.	1	1	1
Chicago, University of, Chicago, Ill.	2	2	2
Christian Brothers College, St. Louis, Mo.	1	2	2
Cincinnati, University of, Cincinnati, O.	6	8	9
Citadel, The, Charleston, S. C.	2	2	2
Clark College, Worcester, Mass.	2	2	2
Clarkson College of Technology, Potsdam, N. Y.	4	4	4
Clemson A. & M. College, Clemson College, S. C.	4	6	5
Cleveland Technical H. S., Cleveland, O.	2	3	3
College of the City of N. Y., New York, N. Y.	1	1	1
Colorado College, Colorado Springs, Colo.	2	2	2
Colorado School of Mines, Golden, Colo.	1	1	1
Colorado State Agri. College, Fort Collins, Colo	5	5	6
Colorado, University of, Boulder, Colo.	9	13	19
Columbia University, New York, N. Y.	15	16	15
Cooper Union, New York, N. Y.	7	6	6
Cornell College, Mt. Vernon, Ia.	2	2	1
Cornell University ,Ithaca, N. Y.	29	27	25

Cumberland University, Lebanon, Tenn.	1	1	1
Dartmouth College, Hanover, N. H.	5	5	6
David Rankin Jr. Sch., St. Louis, Mo.	1	2	2
Delaware College, Newark, Del.	4	3	4
Denver, University of, Denver, Colo.	1	1	1
Dickinson H. S., Jersey City, N. J.	1	3	3
Dorchester H. S., Dorchester Center, Mass.	1	1	1
Drexel Institute, Philadelphia, Pa.	4	9	11
Duval High School, Jacksonville, Fla.	0	1	1
Escola de Engenharia, Porto Alegre, Brazil	1	1	1
Florida, University of, Gainesville, Fla.	3	5	5
Franklin Institute, Philadelphia, Pa.	1	1	1
Franklin Union, Boston, Mass.	4	5	5
George Washington University, Washington, D. C.	2	2	3
Georgia School of Technology, Atlanta, Ga.	1	1	2
Girard College, Philadelphia, Pa.	0	1	1
Government Institute of Technology, Shanghai, China	0	0	2
Harvard University, Cambridge, Mass.	14	15	14
Haverford College, Haverford, Pa.	1	1	1
Hebrew Technical Institute, New York, N. Y.	0	1	1
Highland Park College, Des Moines, Ia.	0	4	4
Idaho, University of, Moscow, Ida.	6	7	4
Illinois, University of, Urbana, Ill.	51	50	47
Indiana University, Bloomington, Ind.	1	1	1
Instituto Technico Professional, Porto Alegre, Brazil	1	2	2
International Correspondence Schools, Scranton, Pa.	4	5	4
Iowa State College, Ames, Ia.	15	17	21
Iowa, State University of, Iowa City, Ia.	7	7	8
James Millikin University, Decatur, Ill.	0	1	2
Johns Hopkins University, Baltimore, Md.	1	4	5
Kansas City M. T. H. S., Kansas City, Mo.	1	1	1
Kansas City N. E. H. S., Kansas City, Mo.	0	0	1
Kansas State Agri. College, Manhattan, Kans.	12	11	18
Kansas, University of, Lawrence, Kans.	9	7	16
Kentucky, State University of, Lexington, Ky.	4	4	4
Lafayette College, Easton, Pa.	1	4	3
Lehigh University, South Bethlehem, Pa.	16	14	14
Leland Stanford Jr. Univ., Stanford Univ., Calif.	5	3	3
Lewis Institute, Chicago, Ill.	3	3	3
Louisiana Industrial Institute, Ruston, La.	0	2	3
Louisiana State University, Baton Rouge, La.	3	3	3
McGill University, Montreal, Canada	3	5	5
McKinley High School, St. Louis, Mo.	1	1	1

McKinley M. T. S., Washington, D. C.	0	1	1
Maine, University of, Orono, Me.	9	9	7
Manitoba, University of, Winnipeg, Man.	3	3	3
Marquette University, Milwaukee, Wis.	1	1	1
Massachusetts Agri. College, Amherst, Mass.	1	1	1
Massachusetts Inst. of Tech., Boston, Mass.	38	38	36
Mechanics Institute, Rochester, N. Y.	0	1	1
Michigan Agri. College, East Lansing, Mich.	17	10	11
Michigan College of Mines, Houghton, Mich.	7	8	7
Michigan, University of, Ann Arbor, Mich.	11	20	24
Milwaukee Public Schools, Milwaukee, Wis.	1	1	1
Minnesota, University of, Minneapolis, Minn.	30	31	31
Mississippi A. & M. College, Agricultural College, Miss.	4	8	7
Mississippi, University of, University, Miss.	1	1	1
Missouri School of Mines, Rolla, Mo.	2	2	2
Missouri, University of, Columbia, Mo.	11	14	15
Montana Agri. College, Bozeman, Mont.	4	5	5
Montana, University of, Missoula, Mont.	2	1	2
Nebraska, University of, Lincoln, Nebr.	12	13	13
Nevada, University of, Reno, Nev.	1	3	3
Newark Manual Training H. S., Newark, N. J.	1	1	1
New Hampshire College, Durham, N. H.	1	2	1
New Mexico Coll. of A. & M. Arts, State College, N. M.	4	3	3
New York Evening High School for Men, New York, N. Y.	0	1	1
New York University, New York, N. Y.	6	7	7
North Carolina Agri. College, West Raleigh, N. C.	4	4	4
North Carolina, University of, Chapel Hill, N. C.	3	5	6
North Dakota Agri. College, Agricultural College, N. D.	2	2	2
North Dakota State Science School, Wahpeton, N. D.	0	1	1
North Dakota, University of, University, N. D.	4	5	5
Northwestern University, Evanston, Ill.	5	6	6
Norwegian Technical University, Trondhjem, Norway	0	0	1
Norwich University, Northfield, Vt.	0	1	1
Nova Scotia Technical College, Halifax, N. S.	4	2	2
Ohio Northern University, Ada, O.	3	2	2
Ohio State University, Columbus, O.	23	29	28
Oklahoma A. & M. College, Stillwater, Okla.	3	4	5
Oklahoma, University of, Norman, Okla.	4	4	4
Oregon Agri. College, Corvallis, Ore.	4	5	5
Oregon, University of, Eugene, Ore.	3	3	3
Pasadena High School, Pasadena, Calif.	1	1	1
Pennsylvania College, Gettysburg, Pa.	1	1	1
Pennsylvania Military College, Chester, Pa.	0	2	2

Pennsylvania State College, State College, Pa.	16	19	25
Pennsylvania, University of, Philadelphia, Pa.	22	26	30
Pittsburgh Central H. S., Pittsburgh, Pa.	1	1	1
Pittsburgh, University of, Pittsburgh, Pa.	8	10	22
Polytechnic School of Engineering, Regents' St., London.	1	1	1
Pomona College, Claremont, Calif.	1	1	1
Pratt Institute, Brooklyn, N. Y.	8	7	7
Princeton University, Princeton, N. J.	2	3	4
Purdue University, LaFayette, Ind.	20	20	19
Queen's University, Kingston, Can.	0	0	2
Queensland, University of, Brisbane, Australia	2	2	2
Redlands, University of, Redlands, Calif.	1	1	0
Reed College, Portland, Ore.	1	1	1
Rensselaer Polytechnic Institute, Troy, N. Y.	5	8	8
Rhode Island State College, Kingston, R. I.	2	2	1
Robert College, Constantinople, Turkey	1	2	3
Rose Polytechnic Institute, Terre Haute, Ind.	3	4	4
Rutgers College, New Brunswick, N. J.	7	6	6
Santa Clara, University of, Santa Clara, Calif.	1	1	1
Sheffield, University of, Sheffield, England	1	1	1
Southern California University, Los Angeles, Calif.	1	1	1
South Dakota State College, Brookings, S. D.	4	6	5
South Dakota, University of, Vermilion, S. D.	1	1	1
St. Johns University, Shanghai, China	0	1	1
Stevens Institute of Technology, Hoboken, N. J.	13	14	16
Swarthmore College, Swarthmore, Pa.	1	2	2
Sydney, University of, Sydney, Australia	1	1	1
Syracuse University, Syracuse, N. Y.	4	8	7
Technical High School, Edmonton, Alberta, Canada	0	1	1
Tennessee, University of, Knoxville, Tenn.	2	3	3
Texas A. & M. College, College Station, Tex.	10	9	10
Texas, University of, Austin, Tex.	4	4	6
Texas State School of Mines and Metallurgy, Fort Bliss, Tex.	0	0	1
Throop College of Technology, Pasadena, Calif.	5	8	8
Tokyo Imperial University, Tokyo, Japan	1	1	1
Toledo University, Toledo, O.	0	0	1
Tome Institute, Port Deposit, Md.	0	1	0
Toronto, University of, Toronto, Canada	8	10	12
Trinity College, Hartford, Conn.	0	0	1
Tufts College, Tufts College, Mass.	14	12	14
Tulane University, New Orleans, La.	3	3	4
Union University, Schenectady, N. Y.	6	7	7

United States Naval Academy, Annapolis, Md.	0	0	2
Universidad de Chile, Santiago, Chile	0	3	3
Utah, University of, Salt Lake City, Utah	8	6	5
Valparaiso University, Valparaiso, Ind.	1	1	1
Vanderbilt University, Nashville, Tenn.	1	1	1
Vermont, University of, Burlington, Vt.	7	8	8
Virginia Military Institute, Lexington, Va.	3	3	3
Virginia Polytechnic Institute, Blacksburg, Va.	4	4	4
Virginia, University of, University, Va.	0	0	6
Washington & Lee University, Lexington, Va.	1	1	2
Washington State College, Pullman, Wash.	1	1	1
Washington University, St. Louis, Mo.	8	6	6
Washington, University of, Seattle, Wash.	13	13	12
Wentworth Institute, Boston, Mass.	9	12	12
West Philadelphia H. S. for Boys, Philadelphia, Pa.	1	1	1
West Virginia University, Morgantown, W. Va.	7	7	7
Whitman College, Walla Walla, Wash.	4	3	3
Williamson Free School, Williamson School, Pa.	2	2	2
Wisconsin, University of, Madison, Wis.	28	26	29
Wooster, University of, Wooster, O.	0	0	1
Worcester Polytechnic Institute, Worcester, Mass.	13	15	16
Worcester Trade School, Worcester, Mass.	1	1	2
Wyoming, University of, Laramie, Wyo.	3	4	3
Yale University, New Haven, Conn.	23	23	23

CONSTITUTION

OF THE

Society for the Promotion of Engineering Education

1. NAME—This organization shall be called the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

2. MEMBERS—Membership in the Society shall be of two general classes, Institutional and Individual.

Institutional members shall be educational institutions giving instruction in engineering and scientific subjects.

Individual membership shall be of two classes, Active and Honorary. It shall comprise those persons who occupy or have occupied responsible positions in the work of engineering instruction, together with engineering practitioners and other persons interested in engineering education.

Honorary Members of the Society shall be such persons as may be recommended by unanimous vote of the Council after a letter ballot. In taking this ballot, the Secretary is directed to close the polls one month after the names of the candidates are sent out. Councilors not heard from will be counted in favor of the candidate. Honorary Members shall not have the right to vote, shall not be eligible to office, and shall not be required to pay any fees or dues.

Any individual member not in arrears for dues may become a Life Member by paying Fifty Dollars into the treasury of the Society at one time.

The name of each candidate for individual membership shall be proposed in writing to the Council by two members by whom he is personally known. In the case of a candidate for Institutional membership the name shall be proposed by any member familiar with the work of the institution on receipt of an application signed by a responsible officer thereof. Such name, if approved by the Council, shall be voted on by the Society at the annual meeting, a vote of three-fourths of those present being required to elect; or, during the period between annual meetings, an affirmative letter ballot of three-fourths of those members of the Council whose vote reaches the Secretary within one month from the time of sending out the name of the candidate shall elect. Such letter ballot elections shall be credited to the previous annual meeting and dues shall date from that time, except that elections to membership occurring after

February 1 shall be credited to the next annual meeting and the dues for the remainder of the year shall be one-half the annual dues.

3. OFFICERS—There shall be a President, two Vice-Presidents, a Secretary and a Treasurer, each to hold office for one year, or until their successors have been elected and have qualified. The Officers shall be elected by ballot of the Society at the annual meeting.

4. COUNCIL—The Council of the Society shall consist of twenty-one elective members, one-third of whom shall retire annually. The Officers and the Past Presidents of the Society shall be members of the Council ex-officio.

Any member of the Society shall be eligible to election to the Council, provided that not more than one elective member shall be from any one college.

Members of the Council shall be elected by ballot by the Society at its annual meeting.

The Council shall constitute a general executive body of the Society, pass on proposals for membership, elect candidates ad interim, attend to all business of the Society, receive and report on propositions for amendments to the constitution, and shall have power to fill temporary vacancies in the offices.

The President of the Society shall be Chairman of the Council, and the Secretary of the Society shall be Secretary of the Council and shall keep the minutes of its meetings and an accurate record of all its actions.

When votes taken by letter ballot of the Council shall be required, all votes which reach the Secretary within one month from the time of sending out the ballots shall be counted, but votes reaching the Secretary later than the time here specified shall not be counted.

5. NOMINATING COMMITTEE—The Nominating Committee shall consist of the Past Presidents and the seven elective members of the Council retiring the following year, provided, however, that if, of this committee, the number in attendance at any meeting be less than five, the President shall make appointments so as to form a committee of five.

6. FEES AND DUES—The admission fee for an individual, active member, which shall also include the first year's dues, shall be Four Dollars ($4.00), and the annual dues, which shall include the subscription price of the BULLETIN, provided for in Art. 8, shall be Four Dollars ($4.00), payable at the time of the annual meeting.

The admission fee for institutional members, which shall also include the first year's dues, shall be Ten Dollars ($10.00), and the annual dues, which shall include the subscription price of three copies of the BULLETIN, and of the PROCEEDINGS, provided for in Art. 8, shall be Ten Dollars ($10.00), payable at the time of the annual meeting.

The fiscal year shall end with the close (or adjournment) of the annual meeting. Those in arrears more than one year shall not be entitled to vote, nor to receive copies of the PROCEEDINGS, and such members shall be notified thereof by the Secretary one month previous to the annual meeting. Any member who has been in arrears more than two years and duly notified by the Secretary, shall be dropped from the roll, until such arrearages are paid.

7. MEETINGS—There shall be an annual meeting at such time and place as the Society at the preceding annual meeting, or the Council may determine.

8. PUBLICATIONS—The publications of the Society shall include an annual volume of PROCEEDINGS, to be published and distributed to the membership as soon as possible after the annual meeting; and a monthly BULLETIN, to be published from September to June, inclusive.

9. AMENDMENTS—This Constitution may be amended by a two-thirds vote of those present at any regular meeting of the Society provided the amendment shall have been approved by the Council by letter ballot by a two-thirds vote of the members voting.

BY-LAWS OF THE SOCIETY AND RULES GOVERNING THE COUNCIL.

First. The Officers of the Society shall constitute a Committee to arrange for the annual meeting and to prepare a program for the same.

Second. The President, the Secretary and the Treasurer shall constitute an Executive Committee which shall have charge of all matters relating to the expenditure of money of the Society, the making of appropriations to Committees and for other purposes, the making of contracts, the approval of bills, and also during the period between the meetings of the Council shall have charge of other business affairs of the Society.

Third. Expenditures of money may be made only in accordance with a definite appropriation or by direct vote of the Executive Committee.

Fourth. Reading of papers shall be limited to fifteen minutes each or to such other time as may be designated by the Program Committee, and abstracts of papers of about three hundred words shall be printed when practicable, and distributed in advance to the members.

Fifth. The time occupied by each person in the discussion of any paper shall not exceed five minutes.

Sixth. The President, the Secretary and the retiring Secretary shall constitute a Publication Committee, of which the Secretary shall be Chairman, to edit and have charge of the publication of the monthly BULLETIN and the PROCEEDINGS of the Society, except the volume of Proceedings of the last convention, which shall be edited by the retiring

Secretary. If at any time there be no retiring Secretary the retiring President shall be a member of this Committee.

Seventh. The Officers, members of the Council and members of the local Convention Committee shall constitute a Committee on Sociability to introduce members and guests to each other at the annual meetings and in general to promote a spirit of good fellowship.

Eighth. The subscription price of the BULLETIN shall be One Dollar per year, payable in advance.

Ninth. Additions or amendments may be made to these By-Laws at any regular meeting of the Society, on the recommendation of the Council by a two-thirds affirmative vote of the Council and of the Society.

PUBLICATIONS.

The publications of the Society can be obtained from the Secretary. The current issues are distributed gratuitously to members in good standing, one copy of each to each individual member and three to each institutional member. The price of the bound volumes of the PROCEEDINGS of former years is $2.50 to non-members, $2.00 to public libraries, and $1.50 to members for their own libraries.

The BULLETIN is issued monthly from September to June. The price to non-members is $1.00 per year. Libraries may order the BULLETIN and the PROCEEDINGS at $3.00 per year.

Reprints of papers may be ordered when the papers are in type form, and either with or without covers, at a price depending upon the number of pages and copies desired.

MINUTES OF THE TWENTY-SECOND ANNUAL MEETING.

PRINCETON, N. J.
JUNE 23 TO JUNE 26, 1914.

The twenty-second annual meeting of the Society for the Promotion of Engineering Education was held at Princeton University, Princeton, N. J., June 23 to 26, 1914. The sessions were held in the Palmer laboratory. Registration headquarters were in the historic Nassau Hall.

TUESDAY, JUNE 23.

Afternoon Session.

The meeting was called to order at 2:30 by President Gardner C. Anthony, dean of the engineering school of Tufts College. He at once introduced President John G. Hibben, of Princeton University, who delivered an address of welcome in which he showed the importance of a philosophic basis for successful engineering of the highest type. In his response President Anthony showed how the philosopher may also be at heart an engineer as in the case of President Hibben himself. This had been shown in Dr. Hibben's work on "Secondary Strains."

The Secretary, Mr. H. H. Norris, presented his report by title. At the request of the Treasurer, whose report was to be presented at a later session, an Auditing Committee was appointed as follows: Professor C. L. Crandall, Director A. J.

Library
N. C. State College

Rowland and Mr. J. C. Ralston. A list of forty-six applications, which had been approved at a Council meeting held at noon, was favorably acted upon by the Society. A list of four applications for institutional membership was also similarly approved.

The Secretary then read the list of changes in the Constitution and By-laws which had been approved by the Council. These changes had been incorporated in the copy of the year-book for 1913–14, the March BULLETIN, and printed there in italics. The changes provided for the new grade of institutional membership, for the reduction of dues for members enrolling after February first, and for a Committee on Sociability. These recommendations for the changes were adopted unanimously. President Anthony then explained briefly the duties of the Committee on Sociability for the members of which special badges had been prepared for use at Princeton.

The President then announced the following names of members of the Committee on Resolutions for the Princeton meeting: Dean M. S. Ketchum, Professors J. C. Tracy and C. A. Holden, and Dean A. H. Fuller.

In introducing Professor D. C. Jackson to present the report of the Joint Committee on Engineering Education in place of the chairman, Mr. Desmond Fitzgerald, President Anthony expressed his opinion of the great importance of the work of this committee. Professor Jackson then gave a brief history of the origin and progress of the committee, quoting from the proceedings of the Cleveland and Detroit meetings of the Society. The original resolutions forming the committee were passed at the Cleveland meeting in 1907 and at the Detroit meeting a resolution was passed authorizing the joint committee to invite the Carnegie Foundation for the Advancement of Teaching to appoint delegates. The next year was spent in gathering the delegates together. After eighteen months spent in organization, during which several meetings were held, an attempt was made to study the catalogues of technical colleges but it was found to be impossible to secure any information from this source suitable for the purposes of the committee. An appropriation was then made by the American Society of Civil Engineers to permit a more elaborate attempt in the same direction, with the same result. The Carnegie Foundation was next invited to undertake the task upon completion of an investigation of medical colleges. The Foundation has now appointed an agent, Dr. C. R. Mann, who will speak at a later session of this meeting. Professor Jackson expressed the opinion that the Joint Committee has done good work and, as the work progressed, fewer fundamental differences of opinion and greater unity of ideals have been apparent in the committee. In commenting on Professor Jackson's report, President Anthony stated that he has become enthusiastic over the prospects of the results of the committee's work although he was not so at first.

President Anthony next called the attention of the Nominating Committee to the constitutional provisions regarding the composition of the committee and then called for the report of the Committee on Entrance Requirements for Engineering Schools. In the absence of the chairman, Professor J. J. Flather, the Secretary read the committee's report which contained certain recommendations regarding manual training.

The Secretary then read a list of the delegates who had been appointed by the institutional members to represent them at the meeting. He also read communications from secretaries of national engineering societies responding to invitations to attend the Princeton meeting. Professor Edgar Marburg, Secretary of the American Society for Testing Materials, then gave a cordial invitation to the members of the Society for the Promotion of Engineering Education to attend the Atlantic City meeting of the A. S. T. M. to be held during the following week.

The Society on motion of Professor D. C. Jackson referred the report of the Committee on Entrance Requirements to the Council with instructions to prepare resolutions in form suitable for adoption at a later session of this meeting. The meeting adjourned at four o'clock to permit the institutional delegates to meet before the reception at "Prospect," the president's mansion, scheduled for five o'clock.

Wednesday, June 24.

Morning Session.

The meeting convened at 9:30 a. m., with President Anthony in the chair. The Treasurer, Mr. W. O. Wiley, presented his report which had been previously distributed in multigraph form. (This report appears later in the minutes.) He stated that the finances of the Society are in good condition and, in answer to questions, explained some of the details of the report. The report was received subject to the report of the Auditing Committee. President Anthony then turned the meeting over to Dean F. L. Bishop, chairman of the Committee on College Administration.

After a brief introduction to the morning's program which had been arranged by the committee, two papers were presented. The first was "The Financial Management of a School or University," by Mr. T. H. B. McKnight, treasurer of the University of Pittsburgh and an official of the Pennsylvania lines west of Pittsburgh; the other was by Professor C. R. Mann, of the University of Chicago, under the title "The Relation of the Administrative Department to the Teacher." Dr. Mann had been recently engaged by the Carnegie Foundation for the Advancement of Teaching to make an investigation of technical instruction methods and facilities.

Before these papers were discussed President Anthony resumed the chair to introduce Hon. James F. Fielder, governor of the State of New Jersey. Governor Fielder addressed the Society briefly, explaining what the State is trying to do in the way of education. President Anthony thanked the Governor for his courtesy and again turned the meeting over to Dean Bishop, who directed the discussion on college administration. He also presented the report of the Committee on College Administration.

President Anthony then resumed the chair and called for the report of the Committee on Statistics, which was read by the chairman, Professor A. J. Wood. This was accepted.

Before adjournment the Secretary read an invitation from Dr. Jewett, of the Western Electric Company, inviting the members to visit the New York laboratories of that company, on the way home from Princeton.

Afternoon Session.

President Anthony called the afternoon session to order at 2:00 p. m. Professor Hugo Diemer abstracted his paper on "Education in Scientific Management" and showed a number of lantern slides of shop forms and equipment.

The Secretary then read an abstract of Professor L. M. Passano's paper on "Academic Efficiency, Undefined and Unrewarded." A written contribution to the discussion of this paper by Professor J. P. J. Williams was read by the Secretary. In response to the call for reports from the four committees on "Improvement in Instruction" in the several branches, Professor F. P. McKibben outlined the report on materials laboratories which had been distributed in the form of galley proofs. Professor Scott also read a report for the Committee on Coöperation in Electrical Engineering Education. The other committees on Coöperation in Engineering Education reported that they had considered the reports presented at Minneapolis as final. There was a general feeling that the work of these committees had not been accurately defined. A full discussion of the topics suggested in the reports followed.

Professor E. R. Maurer reported for the Committee on Teaching Mechanics to Students of Engineering and his report was discussed briefly and accepted as a report of progress. Professor D. C. Miller read the report of the Committee on Teaching Physics to Students of Engineering which led to most interesting discussion as to the place of physics in the engineering curriculum. On motion the report was accepted and the committee was continued.

THURSDAY, JUNE 25.

Morning Session.

The meeting was called to order at 9:30, President Anthony presiding. Professor Crandall reported for the Auditing Committee that the vouchers and bank balances had been examined and found in agreement with the expenditures. A paper on "Practical Mathematics" was then presented by Professor W. S. Franklin on behalf of the authors, Professors Barry MacNutt, R. L. Charles and the speaker. In introducing the paper he referred to the paper by Professor E. V. Huntington which was to follow his and which had been printed in the June BULLETIN. Professor Huntington followed with his paper on "The Use of the Differential in Calculus," and Professor E. R. Hedrick with his, on "The Calculus without Symbols." Professor D. C. Humphreys, Vice-president, then took the chair and presided over the discussion of the papers on mathematics and over the presentation and discussion of the following papers. A paper on "Teaching Engineering Students How to Study," written for the BULLETIN by Professor Geo. L. Sullivan and printed in the May issue, was read by title as a part of the program. This was followed by one on a similar topic "Giving Instruction in Methods of Study," written by Professor W. H. Kenerson and presented in abstract by Professor J. A. Hall. A very profitable discussion followed, including the reading of an extended written communication from Professor Wm. S. Aldrich. This discussion covered both subjects; mathematics and instruction in methods of study.

The convention took a recess at noon for a few minutes to permit the official photographer to make a group photograph and then returned to the lecture room where the discussion, principally on the fundamentals of the calculus, was continued.

Afternoon Session.

The afternoon session began at 2:00 o'clock with President Anthony in the chair. First Professor A. B. McDaniel read his paper on "Co-ordination in Engineering Instruction," which was fully discussed. The paper on "A Study of Technical College Catalogues," by Professor H. S. Jacoby, was briefly abstracted by him and he called attention to an important paper on the same subject by President Henry S. Pritchett in the report of the Carnegie Foundation for the Advancement of Teaching. After a brief discussion Professor C. F. Harding delivered his paper on "Grading of Students by Universities Versus Grading of Technical Graduates by Employers." President Anthony referred to this as one of the most important subjects which had come up for discussion before the Society for some time. Professor A. M. Wilson then read his paper, "A Report on Progress in Co-operative Education," and in response to questions elaborated it considerably. A general discussion based on both of the above papers followed.

Annual Dinner—Thursday Evening.

After the annual dinner held in Proctor Hall, of the Graduate College group, Mr. Knox Taylor and Mr. Chas. H. Higgins spoke on behalf of the Princeton Engineering Alumni Association and President Anthony delivered his presidential address on the subject "Unity in Education." It was not discussed.

FRIDAY, JUNE 26.

Morning Session.

The Society convened at 9:00 a.m. with President Anthony in the chair. The Secretary made a statement of the purposes of institutional membership as he had been requested to do by the institutional members. He said, in substance: "The primary purpose of institutional membership is to bring the educational institutions of the country and the Society closer together. There was a belief that, if the institutions were represented by official delegates these would feel the responsibility of taking back carefully prepared reports of the findings of the Society and the lessons of the meeting which could be made immediately effective. There was not the slightest intention that the delegates should form an inner circle or clique in the Society or that they should have any responsibility other than that stated. They can neither bind the Society nor the institutions which they represent to any policy or action. At the present session two meetings of delegates were scheduled. These were not for the purpose of taking any action and they were open meetings. Their purpose was simply to give the delegates an opportunity to consider how they could best perform their duty to their respective institutions and to summarize the lessons of the convention as an aid in the preparation of reports.''

Professor H. E. Webb presented the report of the Committee on Co-operation with Secondary Schools and this was immediately followed by one on ''Constructive Drawing in High Schools and Engineering Colleges'' by Professor L. F. Rondinella, which had been originally prepared as part of the committee report. After a full discussion a motion was passed ordering the printing of the report and the continuation of the committee.

Professor C. F. Scott then reported that several members of the Committees on Improvement in Laboratory Instruction had held a conference and had prepared the following recommendations regarding the work of these committees:

1. That the committees should be continued.

2. That principal or general reports should be presented successively by the several committees not more than one each year.

3. That each committee should report annually upon the progress of the year and propose topics for discussion.

4. That at each convention one period should be devoted exclusively to the discussion of laboratory work.

5. That each committee should secure for the Bulletin

descriptions of new laboratories, details of equipment, useful methods and laboratory "stunts."

6. That the chairmen should keep each other informed as to the kinds of work undertaken and the methods pursued.

These suggestions were adopted by vote and the continuation of the committees was ordered.

A communication from Professor J. T. Faig, the recently appointed chairman of the Committee on Technical Nomenclature, was read. In this he requested co-operation in the work of the committee. This was accepted as a report of progress and the committee was continued.

The Nominating Committee then presented the following nominations.

For officers to serve for one year:

For President: Anson Marston, State College of Iowa.
For First Vice-president: Henry H. Norris, New York.
For Second Vice-president: C. Russ Richards, University of Illinois.
For Secretary: F. L. Bishop, University of Pittsburgh.
For Treasurer: Wm. O. Wiley, New York.

For members of the Council to serve for three years: R. H. Fernald, University of Pennsylvania; A. H. Fuller, University of Washington; A. M. Greene, Jr., Rensselaer Polytechnic Institute; E. V. Huntington, Harvard University; V. Karapetoff, Cornell University; D. C. Miller, Case School of Applied Science, and W. M. Riggs, Clemson Agricultural and Mechanical College.

On motion the Secretary was instructed to cast a ballot in favor of all the above candidates, which he did.

A resolution of thanks to the retiring Secretary was then unanimously passed, a rising vote being taken. This was followed by the passing of a motion to recommend to the Council the appointment of a committee to prepare standards for use in the compilation of college catalogues. The Secretary read by title a list of resignations which were ordered accepted when the constitutional requirements had been complied with.

The Committee on Resolutions presented the following resolutions which were duly passed:

The meeting of the Society for the Promotion of Engineering Education at Princeton University has been made pleasant and profitable by the many courtesies extended and the Society desires to record its appreciation. Therefore be it

Resolved: that the thanks of the Society be hereby extended to President and Mrs. Hibben and to Dean H. B. Fine and the other members of the local committee for the reception and other entertainment provided for the members and the ladies accompanying the party; to the Princeton Engineering Alumni Association for furnishing guides and for otherwise assisting in the entertainment of the members; to the university authorities for throwing open the Graduate College and other dormitories for the use of the members, and for other courtesies that have made our meetings pleasant and profitable. Further be it

Resolved: that the thanks of the Society be tendered to Mrs. H. B. Fine for providing a luncheon for the ladies and to the local committee for the automobile trip for the ladies; to Mrs. H. Taylor Pyne for providing a tea; to Mrs. D. D. Russell for courtesies; to Mrs. William Libby for the address at Washington's Headquarters; to the Golf Club for extending the privileges of the links; to the Nassau Club for the use of its club house for the smoker; to Governor James F. Fielder for coming to Princeton to deliver an address of welcome, and to Dean W. F. Magie for his most entertaining lecture.

Professor John B. Whitehead then read his paper on "A Department of Engineering at the Johns Hopkins University" and Professor C. E. Lucke, his on "The New Mechanical Engineering Course at Columbia University." After discussion of these papers the convention adjourned.

NON-TECHNICAL FEATURES OF THE CONVENTION.

The report of the Committee on Resolutions suggested the features for which the members were particularly indebted to the local committee and the Princeton hosts and hostesses. The members were largely quartered in the famous dormitories of the graduate and undergraduate colleges and ate together sociably in the dining rooms of University Hall. The local committee and the Alumni Engineering Association furnished guides and transportation and the university business office permitted several of the employees to attend to the business affairs of the convention.

On the opening afternoon President and Mrs. John G. Hibben, assisted by local society leaders, held a reception on the lawn of their home, "Prospect." This was especially appreciated in view of the fact that Dr. Hibben and family were to leave for Europe the following day. A sudden shower drove the guests indoors but in no wise interfered with their pleasure. This social event, coming early in the meeting, "broke the ice" effectually.

Following a custom recently established a "get-together" smoker was held on the first evening of the convention at the Nassau Club and, in spite of the heat, it was very successful. Following a former custom a public lecture was delivered on the second evening by Dean W. F. Magie. The lecturer described the results of his studies of the meteor crater in Arizona which he proved conclusively to have been made by one or more meteors, probably a cluster of them. The lecture was illustrated by pictures and geological specimens.

On the third evening in accordance with another new custom the annual dinner was held, this time in the magnificent Proctor Hall of the Graduate College. It was an event long to be remembered. It was followed by an informal reception and piano recital, with Professor V. Karapetoff as the artist. The presence of the ladies at these events was a feature of their success.

No excursions for the men were provided but the program was so arranged that there were ample intervals betwen sessions for various sports and for conversation. The new Committee on Sociability, suitably badged, was everywhere in evidence and undoubtedly contributed much to the success of the meeting.

Attendance at the Convention.

One hundred and eighty-eight members and guests registered at the convention. The names follow, those of institutional delegates and members registered as representing institutions being indicated by asterisks: C. Frank Allen, G. C. Anthony, Mrs. Anthony, G. F. Ashley. Mrs. Ashley, F. E. Ayer,* C. W. Baker, Frederick Bass, J. L. Beaver, F. L. Bishop,* J. J. Blackmore, J. P. Brooks,* C. G. Brown, Mrs. Brown, L. P. Breckenridge, F. E. Burpee, Mrs. Burpee, J. A. Bursley, S. P. Capen, H. H. Carroll, Mrs. Carroll, R. L. Charles, G. R. Chatburn, Paul Cloke, E. F. Coddington, S. L. Conner,* F. H. Constant, Mrs. Constant, A. L. Cook, C. L. Crandall, Mrs. Crandall, J. S. Crandell, W. B. Creagmile, Hardy Cross, L. F. Curtis, P. H. Daggett, R. H. Danforth, H. H. Deen, J. A. Dent, H. M. Dibert, L. P. Dickinson, W. E. Dickinson, Mrs. Dickinson, Hugo Diemer, Mrs. Diemer, H. S. Drinker, N. M. Emery, J. H. Felgar,* G. F. Fielder, H. B. Fine, A. E. Flowers, F. E. Foss,* M. M. Foss, W. S. Franklin, John Frazer,* H. P. Fry, A. H. Fuller,* Mrs. Fuller, R. W. Gay, A. M. Greene, Jr., Mrs. Greene, T. H. Gronwall, H. V. Gummere, C. E. Haigler, James A. Hall, E. P. Hamilton, C. Francis Harding, L. H. Harris, W. B. Harris, F. E. Haskell,* L. A. Hazeltine,* R. C. H. Heck, E. R. Hedrick,* W. A. Hedrick, N. B. Heller,* John G. Hibben, C. H. Higgins, H. L. Hodgkins,* G. L. Hosmer, H. J. Hotchkiss, C. E. Houghton,* Joseph Hudnut, D. C. Humphreys, J. A. Hunter, E. V. Huntington, D. C. Jackson, J. P. Jackson,* H. S. Jacoby, Mrs. Jacoby, A. R. Johnson, G. R. Jones,* Horace Judd, V. Karapetoff,* Mrs. Karapetoff, E. W. Kellogg, William Kent, M. S. Ketchum, Mrs. Ketchum, R. S. Kirby, O. H. Landreth, J. R. Lapham, H. N. Lendall, C. B. LePage,* O. A. Leutwiler, J. F. Lewis, C. A. Linderman, C. P. Linville, Mrs. Linville, J. J. Long,* W. T. Lyle, F. M. McCullough, A. B. McDaniel, F. P. McKibben, F. W. McNair,* W. T. Magruder, C. R. Mann, Edgar Marburg, J. C. Marriott, E. R. Maurer, M. C. Maxwell, Mansfield Merriman, Mrs. Merriman, D. C. Miller, Hugh Miller, W. E. Mott, J. A. Moyer, W. T. Neel, H. H. Norris, Mrs. Norris, Edmund O'Neill,* C. H. Owen, R. A. Pearson, R. A. Phalen, A. A. Potter,* J. C. Ralston, Master J. W. B. Ralston, E. W. Rettger, C. Russ Richards, W. J. Risley,* L. H. Rittenhouse, Edw. Robinson,* F. H. Robinson, L. F. Rondinella, R. E. Root,* A. J. Rowland, W. B. Russell, C. F. Scott, Mrs. Scott, J. F. Shields, A. L. Smith,* E. B. Smith, H. S. S. Smith, P. F. Smith, F. P. Spalding, S. A. Stephenson, Jr., A. C. Stevens, F. C. Stockwell, R. L. Streeter, W. O. Sypherd, W. H. Tabor, A. N. Talbot, Knox Taylor, Mrs. Taylor, L. B. Taylor, R. G. Thomas,* F. F. Thompson,* J. S. Thompson, C. J. Tilden, W. H. Timbie, A. A. Titsworth, J. C. Tracy, F. E. Turneaure, W. L. Upson, R. L. Wales,* Amasa Walker, E. D. Walker,* H. E. Webb, Chauncey Wernecke, J. B. Whitehead, W. H. Wiley, W. O. Wiley, A. L. Williston, Mrs. Williston, F. N. Willson, A. M. Wilson, C. M. Wirick, A. J. Wood, J. E. Woodman, C. R. Young* (188).

MEETINGS OF THE COUNCIL AT PRINCETON.

Meetings of the Council were held on June 23, 24 and 25. Members who attended one or more sessions were: C. Frank Allen, G. C. Anthony, F. L. Bishop, G. R. Chatburn, C. L. Crandall, D. C. Humphreys, D. C. Jackson, H. S. Jacoby, M. S. Ketchum, F. P. McKibben, F. W. McNair, W. T. Magruder, Mansfield Merriman, H. H. Norris, F. P. Spalding, A. N. Talbot, J. C. Tracy, F. E. Turneaure, W. O. Wiley and A. J. Wood (20). The Secretary read for the information of the Council the actions of the Council by letter ballot and the results of committee ballots taken during the year. He also placed on the blackboard a tabulated statement of the expenditures made during the year as compared with the budget estimates.

The important motions passed were as follows:

1. That the Committee on Statistics be instructed to gather comparative statistics of scholarship in the engineering schools, of students entering respectively from (*a*) the Latin

and English high schools and their equivalents and (*b*) the manual training, technical and vocational high schools of the large cities, reporting these at the next convention.

2. That the Executive Committee prepare an estimated budget of receipts and expenses and present it at the following session of the Council.

3. That a communication from Professor A. M. Greene, Jr., suggesting that the necessary steps be taken to include representation of the American Institute of Chemical Engineers on the Joint Committee on Engineering Education be referred to that committee.

4. That the following change in By-law No. 2 be recommended to the Society for adoption: Line 3 and the following to read, ". . . expenditure of money of the Society, the preparation and presentation to the Council at the annual meeting of a proposed budget for the ensuing year, the making, etc."

5. That the incoming Executive Committee, with the addition of Professors Jacoby and Allen, consider and report to the Council in 1915 on a plan of arrangement of the committee work of the Society.

6. That the incoming Executive Committee, with the addition of Professors Talbot and Magruder, consider the placing of the election of officers and Council earlier in the program with a view to securing greater continuity of interest.

7. That in the opinion of the Council the 1915 meeting should be held in the middle west.

8. That the Executive Committee be instructed to appoint a member of the Society who shall represent the Society on a joint committee on the classification of colleges.

The following applicants were recommended to the Society for election: H. D. Allen, F. S. Bauer, C. G. Brown, R. L. Charles, J. W. Christian, A. R. Cullimore, R. H. Danforth, L. P. Dickinson, Heber Dunham, W. B. Eddison, W. M. Edwards, H. Z. Fay, W. C. Fisk, J. T. Folk, John Frazer, E. M. Garrow, E. P. Hamilton, W. B. Harris, Chas. Haseman, M. P. Helman, H. J. Hotchkiss, W. A. Knapp, Morris Knowles, J. S. Lambie, D. F. McFarland, H. H. Marvin, A. V. Miller, N. C.

Miller, C. C. Myers, W. T. Neel, H. R. Phalen, H. E. Phelp, L. C. Plant, C. B. Price, R. E. Root, H. S. Sheppard, D. W. Spence, W. O. Sypherd, R. P. Thomas, E. L. Usry, E. O. Waters, H. J. Wild, C. M. Wirick, R. L. Witham, D. M. Wright, C. R. Young (46); also Michigan College of Mines, Municipal University of Akron (Ohio), Ohio Wesleyan University, Vanderbilt University.

The following budget of income and expenses for the coming year was reported by the Executive Committee:

Estimated Income.

From current and back dues	$5,700
From advertising	1,000
From publications	500
Total	$7,200

Estimated Expenses.

Treasurer's office, salaries	$ 300
Treasurer's office, sundries	50
Secretary's honorarium	1,000
Secretary's clerical assistance	1,100
Sundry printing	200
Printing Bulletin	1.500
Mailing Bulletin	75
Twenty-year index	150
Committee expenses	100
Printing and insuring Proceedings and reprints	1,400
Editing Vol. 22, Proceedings	100
Drawing and Engraving	100
Postage	600
Expressage	75
Telegrams	15
Office sundries	50
Expenses Princeton meeting	300
Total	$7.115

Respectfully submitted,

Henry H. Norris,

Secretary.

COUNCIL LETTER BALLOTS TAKEN DURING 1913–14.

August 1, 1913.—The Council approved the minutes of the Minneapolis meeting and elected the following applicants: G. J. Baldwin, D. J. Demorest, F. B. Seely, C. A. P. Turner (4).

November 15, 1913.—The Council elected the following applicants: (Individuals) F. G. Allen, T. A. Blair, I. C. Crawford, G. H. Denny, A. B. Domonoske, F. R. Finch, J. M. Gallalee, Roy Kegerreis, R. B. Keller, J. A. Kostalek, L. Mitchell, A. S. Naidu, H. C. Phillips, J. C. Potter, R. W. Thoroughgood, G. D. Walters (16); (Institutions) University of California, Case School of Applied Science, Clemson Agricultural and Mechanical College, George Washington University, Georgia School of Technology, Harvard University, Iowa State College, University of Kansas, Miami University, New York University, University of North Dakota, University of Notre Dame, University of Oklahoma, Rhode Island State College, Rochester Athenaeum and Mechanics' Institute, Stevens Institute of Technology, Syracuse University, Throop College of Technology, United States Naval Academy, University of Washington, Worcester Polytechnic Institute (21).

December 5, 1913.—The Council elected the following applicants: (Individuals) C. J. Belsky, Geo. J. Davis, Jr., G. G. Durham, Hollis Godfrey, Wm. F. Johnson, Geo. R. Moore, G. D. Newton, R. R. Sellers, J. J. Strong, J. F. Wilson (10); (Institutions) Cornell University, University of Michigan, University of Pittsburgh (3).

January 1, 1914.—The names of thirty-three members were removed from the role on account of non-payment of dues.

January 24, 1914.—The Council elected the following applicants: (Individuals) J. M. Bell, A. E. Bellis, R. C. Carpenter, G. A. Chaney, M. A. Charavay, H. R. Codwise, M. W. Dougherty, J. A. Ely, I. W. Fisk, S. G. George, H. B. Gummere, J. A. Hall, J. M. Henderson, G. P. Hitchcock, G. L. Hosmer, Hale Houston, H. S. Hower, F. B. Jewett, A. P. Little, H. B. Luther, S. L. MacDonald, H. D. McMurtray, W. L. Miser, J. R. Nelson, P. C. Nugent, C. T. Olmsted, R. A.

Pearson, G. H. Radebaugh, P. L. Reed, J. E. Robertson, A. E. Salazar, L. F. Seaton, T. C. Shedd, R. H. Skelton, R. R. Smith, Wm. Y. Smith, L. C. Starkey, W. B. Stelzner, C. H. Sutherland, W. H. Tabor, Franklin Thomas, R. E. Thompson, R. L. Wales, W. M. Wilson, J. W. Winter, S. S. Yates, E. N. Zern (47); (Institutions) Drexel Institute, the State University of Iowa, University of Nebraska (3).

February 15, 1914.—The Council elected the following applicants: (Individuals) H. C. Bird, H. P. Boardman, Frank Bogard, G. M. Braune, A. I. Brown, Mrs. K. D. Brown, W. H. Clapp, J. R. Cockburn, J. S. Eaton, A. O. Gates, R. D. George, K. E. Guthe, W. R. Ham, F. E. Haskell, S. J. Hoexter, G. J. Hood, L. R. Leonard, W. T. Lyle, E. R. Maclin, R. S. Naidu, G. G. Pond, S. R. Pritchard, J. T. Rood, F. W. Roys, C. S. Sperry, W. D. Tallman, C. H. Thurber, Amasa Walker, H. L. Watson, G. S. Wheatley (30); (Institutions) University of Missouri, Pennsylvania State College, University of Pennsylvania, Princeton University, University of South Carolina, Tufts College, University of Wisconsin (7).

March 25, 1914.—A ballot was taken to ascertain the opinion of the Council regarding the time and place of the 1915 meeting. A preliminary ballot (unrecorded) showed a fairly even division of opinion for and against California. This ballot resulted in 24 votes for, 5 against and 6 for, with qualifications, a meeting at Stanford University or the University of California early in September, 1914.

March 25, 1914.—The Council elected the following applicants: (Individuals) C. E. Albert, Jens Bache-Wiig, W. G. H. Brehmer, D. E. Buyers, R. T. Callaghan, H. H. Denn, C. L. Harris, G. E. Hesse, H. R. Huelle, August Hund, W. C. Huntington, R. L. James, G. R. Jones, John McGowan, H. M. MacKay, C. R. Mann, M. S. Munro, T. S. Patterson, Louis Roark, Daniels Scoates, J. G. Scrugham, E. L. Shattuck, F. C. Stockwell, Arthur Surveyer, John Weber, H. J. Wild, A. E. Winslow (27); (Institutions) Alabama Polytechnic Institute, University of Arizona, Brown University, The Citadel (The Military College of South Carolina), Lehigh University, Rutgers College, The Temple University, The Thayer School of Civil Engineering of Dartmouth College, University of Utah, Washington University (10).

New Members During 1913–14.

The total number of new members to be credited to the Minneapolis meeting is 229 individuals, of whom 95 were elected at the meeting and 134 during the year, and 44 institutions.

TREASURER'S REPORT FOR 1913–1914.

To the Society for the Promotion of Engineering Education:

The Treasurer would respectfully report the condition of the Society's finances as follows:

Comparative Balance Sheet 1912–1913 and 1913–1914.

Assets.

Accounts Receivable.	1914.	1913.	Increase.	Decrease.
Back dues	$ 279.54	$ 253.50	$ 26.04	
Current dues	1,055.22	815.60	239.62	
Advertising and Publications	419.46	489.36		69.90
Cash, Lincoln Tr. Co.	1,340.59	1,453.14		112.55
Union Sq. Savings Bank	371.05	310.12	60.93	
Inventory of publications	3,937.55	3,942.75		5.20
			326.59	187.65
			187.65	
	$7,403.41	$7,264.47	$138.94	

Liabilities and Surplus.

	1914.	1913.	Increase.	Decrease.
Members dues paid in advance	$ 103.85	$ 105.29		$ 1.44
Non-members and Acct. Payable*	276.90	.99	275.91	
Surplus	6,651.61	6,848.07		196.46
Life membership	371.05	310.12	60.93	
			336.84	197.90
			197.90.	
	$7,403.41	$7,264.47	$138.94	

* There are outstanding accounts for which bills have not been presented. As far as the Treasurer's accounts are concerned such become payable only when audited.

Trading Account.

June 18/13		
Inventory	$3,942.75	
Cost of Publication (Schedule F)	4,122.16	
	8,064.91	
Less Inventory on hand June 18/14, (Schedule G)	3,937.55	
Cost of Sales		$4,127.36
		$4,127.36
Sales of Publications:		
Sales to members and non-members	1,033.62	
One-fourth of individual members' dues	1,276.50	
Three-tenths of institutional members' dues	117.00	$2,427.12
Advertising	1,261.25	
Less discount	21.67	1,239.58
Balance—profit and loss a/c loss		460.66
		$4,127.36

Profit and Loss Account.

To trading account	$ 460.66
Expenses, Minneapolis Meeting (Schedule H)	235.70
Expenses, Princeton Meeting (Schedule I)	16.75
Secretary's office expenses (Schedule J)	3,111.56
Treasurer's office expenses (Schedule K)	259.39
	$4,084.06
Profit for year	115.50
	$4,199.56
Dues, individual	$3,829.50
Dues, institutional	273.00
Discount received	65.87
Interest on bank balances	31.19
	$4,199.56

Balance Sheet.

Assets.

Accounts receivable:		
Members: back dues (Schedule A)	$ 279.54	
Members: current dues (Schedule B)	1,055.22	
Members and non-members, Adv. and Publications (Schedule C)	419.46	1,754.22
Cash—Lincoln Trust Company	1,340.59	
Cash—Union Square Savings Bank—Life Membership Fund	371.05	1,711.64
Inventory of publications		3,937.55
		$7,403.41

Liabilities and Surplus.

Members: dues paid in advance (Schedule D) . .	$ 103.85	
Non-members and accounts payable (Schedule E)	276.90	
Total		380.75
Surplus—June 18, 1913	6,848.07	
Less dues from members dropped or resigned and accounts uncollectable	311.96	
	6,536.11	
Profit for year	115.50	
	6,651.61	
Life membership	371.05	7,022.66
		$7,403.41

MEMBERSHIP.

		Changes During the Year.			
	No of Mem.	Individual.	Institutional.	Res. or Dropped.	Total.
June 1911	1071	114	. .	83	1102
" 1912	1102	107	. .	51	1158
" 1913	1158	215	44	59	1358
" 1914	1358				

It will be noted that the Treasurer's accounts are kept in accordance with the following schedules, which are not printed as they are quite extensive. These schedules are kept filed for reference by members of the Society in the Treasurer's office. (A) Back dues. (B) Current dues. (C) Accounts receivable for advertising and publications from members and non-members. (D) Members paid in advance. (E) Due non-members. (F) Printing (sundry, BULLETIN, Proceedings and reprints), drawing and engraving and editor's salary. (G) Inventory of Proceedings, BULLETIN and reprints, (H and I) Expenses of meetings, (J) General expenses such as postage of all kinds, telegrams, advertising of publications, expressage and freight, clerical assistance, insurance, committee expenses, Secretary's salary, etc., (K) Expenses of the Treasurer's office.

Respectfully submitted,

W. O. WILEY,
Treasurer.

SECRETARY'S REPORT FOR 1913–1914.

There is nothing of special interest to report this year except to state that an endeavor has been made to carry out the instructions of the Council and to systematize the work so that it could be turned over to the next secretary in as complete a form as possible. The Secretary has had effective co-operation from Mr. A. C. Stevens and Miss Edith M. Wilkinson, who have attended to much of the routine work of the Society.

The Secretary had the opportunity of visiting a large number of educational centers during the year and found much interest in the work of the Society in each.

The accessions to the membership have been unusually large this year as a result of the operation of the following plan: Each member in an educational institution was asked to furnish, on a convenient form, a list of possible members in his own and allied departments. On each sheet sent out was a list of all local members. The response to this request was general and an excellent list was prepared as a result. The men whose names were suggested were invited to join and printed matter was sent. To many sample copies of the BULLETIN were mailed under the post-office regulation allowing ten per cent. of the number of the paid circulation to be sent out as sample copies. The members of the Society were also requested to invite their friends to join. The institutional membership has made an encouraging start with about fifty institutions. Very few invited have declined and about one-half have joined. It is only necessary to demonstrate the value of such membership to double the number of institutions on the roll.

The members have responded readily to requests for contributions to the BULLETIN and there is always more copy on hand than can be immediately used. As the publication is always three months or more behind the receipt of papers, members should be patient with the Publication Committee.

The publications have circulated well this year under the influence of an active advertising campaign. Nearly 10,000 circulars advertising the Syllabus of Mathematics have been sent out and the result has been satisfactory. A large number of volumes of PROCEEDINGS have also been sold.

A plan was put into operation which has simplified retail sales and relieved the Treasurer's office of a mass of detail. The weekly sums of money collected through the Secretary's office during the year have been surprisingly large. The routine is this: When an order is received it is filled from the Secretary's office or from Lancaster (in the case of large orders) and a triplicate statement or invoice is made out in one operation. Each has a serial number. One is sent to the purchaser and acts as a bill, one is retained as a permanent record, and the other is retained until the remittance is received when it is forwarded with the remittance to the Treasurer. The same procedure is followed with dues paid through the Secretary's office and with all entrance fees. The remittances are forwarded to the Treasurer when from $50 to $100 has accumulated, *i. e.*, every week or two in the busy season, accompanied by a check list.

The Secretary's office has, as far as possible, standardized all routine operations and has records of the sequence of duties following the receipt of an application, the death of a member, the publication of an issue of the BULLETIN, etc. Scrap books contain samples of all forms, printed or otherwise duplicated.

The endeavor has been made each year more strongly, to keep the Council posted as to every detail of the work as it progresses during the year. Frequent circular letters have been sent the members and the result is a very large ballot on every question submitted for ballot.

The Society has purchased for the Secretary's office, from time to time, the necessary appliances and we have now excellent furniture for filing purposes and typewriter, small printing press, etc. As this equipment is not inventoried in the Treasurer's report it is mentioned here for purpose of record.

On retiring from the secretaryship after five years the present incumbent desires to record the sense of pleasure and appreciation which he feels and his regret that his present professional work is of such a nature that routine work for the Society can be no longer carried. There could not be a more satisfactory line of work as the field is large and co-operation unlimited. The Society has a most loyal membership which responds to every appeal.

Respectfully submitted,
HENRY H. NORRIS,
Secretary.

APPENDIX.

BULLETIN ADVERTISING BY MONTHS.

Month.	1912–13.	1913–14.
September	$112.75	$135.50
October	137.00	118.50
November	101.00	130.00
December	157.00	113.50
January	132.00	126.25
February	118.75	123.00
March	113.75	134.50
April	111.25	131.00
May	104.25	125.75
June	108.75	121.25
Total	$1,196.50	$1,259.25

ADDRESS OF WELCOME ON BEHALF OF PRINCETON UNIVERSITY.

BY JOHN G. HIBBEN,

President of the University.

President Anthony and Members of the Society for the Promotion of Engineering Education: We feel highly honored that you have chosen Princeton for your meeting at this time. We teachers of non-engineering subjects look upon you with a great deal of envy, particularly those in my own profession, the teaching of philosophy, for we have nothing that is tangible, nothing that is visible, to deal with. So we must fall back upon the ideas within our own minds and those which we can gain from books. You are dealing with the substantial realities of life; your work is visible to all. It was a member of one of your professions, was it not, who when twitted by a medical friend in regard to a monument which he had made, turned and said, "My dear sir, our mistakes are above ground; yours are all beneath it." Not only are the mistakes of engineers above ground, but their successes are above ground also. I look upon the engineering profession with a great deal of pride for what it has accomplished, particularly within the last generation. This sentiment I shared with Mr. Grover Cleveland who, when a resident at Princeton said to me, in referring to his young son, "I would rather see that boy become a man able to build a great bridge than anything else in the world." This man of affairs, this great administrator and statesman, desired for his boy the ability which you, as engineers, possess.

You are dealing with the material things of life, your problems are presented to you in substantial form, you can have them before you, and yet you are not dealing wholly with particular instances or with the material situation in your thinking. A few years ago a young mining engineer went West from Princeton. He returned after a time and I took the opportunity to ask him his opinion as to the chief element in the success of a young engineer. After a moment's thought he replied, "He should be a man who does not lose his head when he finds himself confronted by a new situation." That, I take it, is a very fair definition. It is the new situation which confronts one that is important.

In taking up a new piece of work the engineer might say that it is like a piece of work upon which he was engaged a year ago and proceed, with formulas ready at hand, as he had done before. Perhaps an engineer could have conducted his enterprises in that way twenty-five years ago but he could not do so at the present day, with the accelerated speed at which the professions are moving. In the new situations which confront one day by.day new problems must be solved. In studying their problems, engineers become philosophers. Perhaps you may not like that classification; but remember that Aristotle defined the philosopher thus: "All mankind is divided into two classes. There are the men who know the past, and this is most valuable information, then there are those who know the causes of these facts. The latter are the philosophers."

We shall accept that definition, and classify the engineers henceforth as philosophers. More than a generation ago, the eminent mathematician Professor Griffith drew a distinction between the technical engineer and the scientific engineer. By "scientific engineer" he meant what Aristotle meant when he spoke of the philosopher as the man who understood the causes of facts and things. Professor Griffith cited as a typical example of the scientific engineer, Professor Fleeming Jenkin.

I have said that you deal with things, the substantial entities. You do, and you do not, for if you dealt merely with brick and mortar, with reinforced concrete, and only that, you would make no progress. All the material things must be taken up in the mind, and upon them there must be a play of ideas. We speak of working with concrete instances, but back of the concrete instance there must be the grasp of the abstract principles of mathematics, physics, mechanics, and so on, through the whole range of the philosophy of nature. The man with

Library
N. C. State College

this grasp is he who commands the tangible, the particular, situation. You are allies of nature, whose laws are not merely a limit set to your operations. They are suggestions to you of the means you must employ to effect certain ends.

In a current theory of pragmatism is the idea that the only test throughout the world is a verification, a putting to the test. Engineering is the profession, of all professions, that does not dare to proceed by trial and error. When a bridge is built it will not do to wait for the first train to go over it and test it. The designer must know beforehand that it will bear a certain load with a comfortable factor of safety. This can be done by the man with a grasp of universal fundamental principles. To the extent to which he has such a grasp he is able to speak with authority. I do not believe there is any other profession in which the end of an enterprise is known from the beginning. These enterprises must constitute an unbroken line of successes. Experimenting may be done in the laboratories, but when an actual enterprise is entrusted to the engineer's hands, he must be able to say to his clients, "I know what the result will be."

There is the supreme test in the final verification when work is finished and put to use, but that is not the fundamental ground of truth, which must lie back of that in the fundamental principles. This is a constant spur in the engineer's work, that, by the very nature of the profession, whatever is undertaken must be done supremely well. The philosopher may write an essay which, when published, may be torn to pieces and in a few years he may be compelled to confess it a total failure. But it is not so with the engineer's work which must stand or fall and, as it stands or falls, tests the integrity of the worker. No one has more graphically described this than Rudyard Kipling, who tells of a young man who built a bridge over the Ganges River. When a great flood arose this young engineer sat by his bridge through all the darkness of the night and its storm, watching it, for he felt that he would be judged by the result. As he watched the storm and the bridge, he thought of a fellow engineer whose great waterworks had been swept out to sea. He remembered that this man had died of a broken heart. He remembered another young man whose bridge had been swept away by a storm, and the shame on the man's face after the disaster. Then he said, "In my profession no excuses are taken. The Government may listen to me when I make my report; but I shall be judged by the men of my own craft, and by my bridge, whether it stands or whether it falls."

RESPONSE ON BEHALF OF THE SOCIETY.

BY GARDNER C. ANTHONY,

President of the Society.

President Hibben: I have the privilege and pleasure of expressing to you the appreciation of this society for your warm welcome and for your excellent words concerning engineering. I accept your definition and I shall go farther and accept the philosopher as an engineer. You have already qualified as an engineer by writing your essay on "Secondary Strains." I think I may term this your thesis on secondary strains, by which you have qualified in engineering.

You have gone farther than to consider the secondary strains in materials. While the weakness of the materials proved disastrous in the Quebec Bridge, to which you alluded, you have dealt with the more important Secondary Strains of character. Certainly the loss of character is greater than that of material construction. We welcome you, therefore, to the profession of engineering.

ADDRESS OF WELCOME ON BEHALF OF THE STATE OF NEW JERSEY.

BY HON. JAMES F. FIELDER,

Governor of the State of New Jersey.

Mr. President, Ladies and Gentlemen: When the invitation was extended to me to attend this session I was glad that my engagements were such that I could come in a sort of official capacity and say to you that the State of New Jersey feels very much honored that you have chosen our State, and this place in our State, for your meeting. I feel very fortunate, indeed, that I happen to be the one who occupies the chair of Chief Executive at this time, so that I have the privilege of presenting to you an official welcome on behalf of all our citizens.

When you opened your session yesterday the freedom of Princeton was extended to you. I want to extend that freedom, if you desire to go outside the confines of this beautiful town, and assure you that all of us in the State will be very glad to have you visit our other communities. We believe that the people of New Jersey are among the most hospitable people in the country, so that, in extending to you the freedom of the State of New Jersey, I do so with the assurance that you will be made heartily welcome wherever your inclination leads you.

To those of us who have been educated in other professions engineering is very much of a mystery and I am not going to attempt to speak to you on that subject. We see only the result of your research work, your achievements, your works of construction, and we marvel that it is possible for the brain of man to accomplish them with such accuracy.

But I do know something of the interests of the State of New Jersey in educational matters. Having been connected with our State Legislature for several years before I became Governor I have had the opportunity to see what the State has been doing in educational lines. I believe that there is no other state of the Union which devotes, in proportion to its population, more time, attention and money to the cause of education. Our public schools, including high schools and normal schools, are State institutions supported by State contributions to a very large extent. You know for yourselves what our colleges are, what work they are doing and what progress they are making along modern educational lines. I believe that your meeting here will mean not only a great deal to you but that it will also serve as an incentive to us.

I am looking forward with pleasure to being present to-night at the commencement of a Normal School where several hundred young men and women will be graduated, after a thorough and systematic training has been given to them. Most of them will become teachers in this State. I believe that the Newark Normal School, also, graduated last evening nearly one hundred and fifty young men and women of whom practically all have already secured positions as teachers, mostly in this State. You see, therefore, that as far as teaching is concerned we are doing our part in turning out well-equipped and trained teachers. Some of these will take up higher courses perhaps in engineering.

In conclusion let me express the hope that you will have a profitable, interesting and pleasurable session; that you will so enjoy your visit that you will wish to come again.

RESPONSE ON BEHALF OF THE SOCIETY.

BY GARDNER C. ANTHONY,

President of the Society.

Your Excellency: On behalf of this society I wish to express sincere appreciation both for your presence and for your kind words of welcome. We have sensed this welcome ever since we entered your domain, and to an increasing degree. It will be our desire and earnest effort to do something to contribute to the welfare of education here, as you have already done for the states of the Union. It is one of the helpful and healthful signs of the times that we are to-day realizing the spirit of coöperation among states, cities and educational institutions. It is particularly gratifying to-day that we have in you both the representative of the State and the President of the Board of Trustees of Princeton University.

ADDRESSES OF WELCOME ON BEHALF OF THE PRINCETON ENGINEERING ASSOCIATION.

BY KNOX TAYLOR,

President of the Association.

Mr. President, Ladies and Gentlemen: In speaking for the Princeton Engineering Alumni Association I wish to say that we are greatly pleased to have this visit from the Society for the Promotion of Engineering Education. Your visit cannot but stimulate Princeton's interest in engineering. Princeton has taken on new activity in this direction; and I am sure that in her plans for the future she will be largely guided by the deliberations of your excellent society. It is a very great pleasure to us to have you here.

We appreciate the reference your President has made to our Society.* Princeton has not a large body of engineering alumni but they are very active.

I assure you again of the pleasure we have in welcoming you here and I hope your visit will mean as much to you as it does to us.

BY CHARLES HOUCHIN HIGGINS,

Secretary of the Association.

Mr. President and Members of the Society: It is a real satisfaction to take part in extending Princeton's welcome to you. Since those days two years ago when, with the atmosphere at a similarly high temperature, I made your acquaintance in Boston, I have wanted to see you in Princeton. It is an honor to have you here. We expect and trust you will do us good and we hope that your stay in Princeton will do you good; that you may receive from Princeton's spirit and traditions and find an atmosphere well suited to the carrying on the conferences and the working out of results, which are the reasons for your coming together.

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* In introducing Mr. Taylor President Anthony had referred to what the Society has done.

To all of you, interested as you are in the education at our colleges, the opinion of Mr. Larry Doyle, of the New York Giants, will be encouraging. After witnessing the recent Princeton-Yale baseball game in New York, Mr. Doyle confided to the daily press, that "You certainly can learn as much at these colleges as you can in any bush league in the country."

Princeton has, from the first, taken her part in preparing men for the nation's service. But the service required varies from generation to generation. To-day, the engineer is required as never before in the history of our land. I do not express this as my opinion, but as the opinion of the man on the street. Between the Revolution and the Compromise of 1850, one and one half billion acres of land were added to the public domain and of these the fertile sections were given to the settler almost for the asking. Swift settlement of this vast territory gave abundance, resulting in cheapness and plenteousness of food, clothing and shelter. Probably in no period were the people so easily fed as during this time of public land distribution in the United States.

Now the country is filling up, the land is occupied, and we have come under the law of diminishing return. In the period referred to, the virginal fertility of the soil was reduced, large trees, near at hand, were felled and minerals near the surface or otherwise easy of access, were removed. The old, free-handed, wasteful days have passed. A result of the application of the law of diminishing return is the high cost of living.

The country has been skimmed. Only by new processes and by exact methods which, I take it, is what engineering is, may we hope to maintain our standards. An engineer has been defined as a man able to do for one dollar what anyone can do for two. It is because of the hope that this is true that people are turning to the engineer. The West is in advance of the East in much of the new development, but everywhere there is an awakening and turning with hope to engineering training. This is shown in increased consideration and honors accorded to engineers.

If the hope of the nation for better conditions is to be realized, the results must come from the training that you men are providing in the colleges. This movement is only in its beginning, hence the importance of conferences such as these. Methods must differ in different places, as there must be differences in needs and material, but there is a broad underlying basis of this thing called engineering education, which you gentlemen have come together from all over the land to find out through interchange of views.

Princeton's determination to extend her engineering courses is not a change, but a development of her oldest and most cherished traditions, to train men for service.

I cannot close without saying a word regarding the Princeton Engineering Association, which was formed a few years ago among the alumni of Princeton interested in engineering. We found such associations existing among the alumni of some colleges and received real assistance in forming our association from the Harvard Engineering Society. In fact, it was from the workings of that Society that our determination to form an association was inspired. It has been a lot of fun for us and we hope of some use to the University. At any rate, it has been of real use to us, making us better acquainted with each other and with the members of the faculty, with whom some of us who had been out of college for a time had fallen out of touch.

RESPONSE ON BEHALF OF THE SOCIETY.

BY GARDNER C. ANTHONY,

President of the Society.

Messrs. Taylor and Higgins: On behalf of the Society I thank you and the Princeton Engineering Alumni Association for your cordial welcome and for the part which you have had in connection with this meeting. I have been at work with you, in the interests of this Society, for two years past and I know that you and the other officers of your Association have been responsible for much that we have enjoyed here.

UNITY IN EDUCATION.

Presidential Address.

BY GARDNER C. ANTHONY,

Dean of the School of Engineering, Tufts College.

The first paper printed in the proceedings of this Society treated of "The Ideal Engineering Education," and although we have realized somewhat of this ideal during the twenty-one intervening years, no serious-minded educator can rest satisfied with the present condition. Our technical colleges and high schools, together with the allied interests of the industrial and vocational schools, are creating new ideals necessitated by modern demands until the goal of the engineering educator is still just over the horizon. As it is the business of this Society to deal with ideals, as well as to discover the means for their realization, I shall avail myself of the privilege accorded the President for the free expression of his own theories and experiences to review certain phases of the development during these twenty-one years, with the acknowledged intent of focusing your attention on one ideal which I believe should exert a powerful influence in promoting greater unity in education.

Almost the entire history of engineering education dates from the Civil War, previous to which there was little instruction of an engineering character given. But during the period from 1861 to 1876 the pioneer work was done and the foundation laid for a new type of education built of new methods for scientific training and new subject matter. From that time the demand for trained men to fill a new profession has developed an issue between the so-called cultural and vocational courses, which has widened the breach between these two forms of education causing a prolonged controversy largely based on misunderstandings. This was partly due to the addition of new subject matter, but more particularly resulted from the tendency to abandon courses which were formerly regarded as essential to academic education. The decline of the lecture system and the development of laboratory methods, together with an approach to affiliation between theory and practice, have forced the higher education out of the cloister and into the market place with its attendant good and evil.

Much of this division was due to a failure on the part of educators to appreciate the inadequacy of the older pedagogical systems to meet the requirements of new science teaching, and also to the reluctance of teachers to abandon, or suffer an abbreviation of, subject matter which was supposed to possess some inherent cultural value apart from its educational uses. This evil has been most noticeable in institutions out of which technical schools have grown and in which not infrequently a conflict between the two ideals has continued for years. It has resulted in a shallowness on the side of letters due to too great freedom in election, and a narrowness on the side of engineering due to too great specialization. Unless my view of the situation is badly distorted it would appear that the educational pendulum has now reached its extreme oscillation toward vocational education and is about returning toward that point which should mark a greater unity in the objects of education regardless of the diversity of paths which must ever tend to become more divergent. May not the time be near at hand when we shall cease the attempt to make an engineer during the undergraduate period but more broadly prepare him for the graduate school of experience; when we shall think less of educating engineering specialists and more of men, well trained in character as well as mind; when it will not be a question of Greek or thermodynamics but of the best all-round training for the individual.

The present educational chaos through which we are passing is the product of influences scientific and pedagogical, economic and sociological, which have developed largely within the lifetime of this Society. But, until the present day, no serious attempt has been made to study the great field of engineering education in college and secondary school, in shop and industrial school, as well as to determine the relation of the engineering school to its prototype the American college. In 1907, Professor Dugald C. Jackson, then President of this Society, proposed the appointment of a joint committee representing the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Chemical Society and the Society for the Promotion of Engineering Education, to "examine into all branches of engineering education, including engineering research, graduate professional courses, undergraduate engineering instruction, and the proper relations of engineering schools to the secondary industrial schools or foremen's schools, and to formulate a report or reports upon the appropriate scope of engineering education and the degree of coöperation and unity that may be advantageously arranged between the various engineering schools." Unforeseen delays have prevented the realization of this end until the present year, when, as you have already learned, the work is not only organized but actually begun, being conducted under the auspices of the Carnegie Foundation for the Advancement of Teaching. What the findings of this board may be we cannot predict at present but they will surely be of great assistance in solving some of the educational problems which confront the engineering institutions of to-day.

Engineering, having become a profession, is demanding an education supposedly distinct from other types. Manual training and commercial schools have been established as forms of high-school training; industrial and vocational education is striving for recognition in the public school systems, and the war-cry of efficiency has gone into the very sanctum of the educational cloister. Can it be that we of this age are so unique in our mental development that we differ greatly from the educators of past centuries, or is it that the melting pot of our day contains so much of a high-speed mixture that our composition' bears no likeness to that which was worked without the aid of the high-pressure modern educational systems? Permit me to draw a sample of this mixture for your analysis.

When we remember that the greater number of technical schools have been a growth from the old type of college and not on an independent foundation, it will account for some of the differences which have grown up between letters and science. This was fostered by an apparent encroachment on the prerogatives of the former and seemed to tend toward a prostitution of learning to trade. In this type of institution the growth of engineering has frequently resulted in its segregation from the school of letters and the organization of an engineering department, or school. with its own faculty and independent courses. These new schools have tended to depart from the recognized essentials in subject matter and treatment. promoting an unwholesome competition antagonistic to unity in sentiment and action. The neglect of the classics for subjects of a utilitarian character resulted in a defense of subject matter in place of its readaptation to changed ideals and modern demands.

A second type of institution is that which has had a separate foundation and is of an acknowledged scientific or engineering character. This type has done yet more to widen the breach between the old and new education by independent development toward a definite technical training. For fifty years schools of this type have been founded and developed along the lines which were laid down ,with such apparent wisdom by the pioneers of technical education and these schools have been influencing rather than being influenced by the schools of the first type which were grafted on the parent stock.

A third type is that of the state institution in which both academic and scientific courses have been planted at the same time and grown up in comparative harmony. although they have been greatly influenced in their aims and methods by their prototypes, the American college and the technical school.

Having been closely identified for more than twenty years with the creation and development of a technical school in a college of the first type, I can enumerate some phases of this development which must be common to institutions of that class and may help to characterize the educational mixture now being submitted for analysis. My object in so doing is to consider the treatment of these evils for their elimination and the production of a greater unity in education.

The first step in the historical development of an engineering department was commonly through the expansion of the scientific courses already existing, and the introduction of new courses which were of a distinctively engineering character. These changes required faculty approval and more or less concerted action on the part of those interested in the new department. This was naturally followed by special committees, or administrative boards, leading to partly related, or independent faculties, and separate schools. With the increased registration in engineering schools and the corresponding decrease in the number of liberal arts students, a sense of fear was developed for the maintenance of educational standards which seemed to be threatened by a loss of interest in subjects supposedly essential to a liberal education. Such a state of mind was not conducive to a sympathetic interest in a movement toward the readaptation of the subjects commonly taught to meet the new conditions, but rather tended toward distrust of a movement which threatened such a disturbance in educational creeds. This was most marked in the older colleges out of which technical schools had grown, and where not infrequently engineering students were made to feel that they belong to a different, if not an inferior, class. It led instructors in the school of letters to expect less of the engineering students in such courses as language and thus created a lack of confidence in, and distaste for, subjects taught by the schools of liberal arts. Such of these subjects as were prescribed to the engineering students were generally conceded to be a sort of cultural dose which would be efficacious in neutralizing the professional tendency of the education, but with which it had little relation.

This regard for subject matter which might be possessed of some latent influence, the exposure to which might produce some efficacious results, has been a fetich too long worshiped not only by schools of liberal arts but by engineering schools, and has led to much of the controversy which has divided schools of art and science. It has been chiefly responsible for the shortening of the arts course so as to insure the getting of a cultural spray before immersion in a technical bath supposedly free from cultural germs, or it has lengthened the engineering course to five and six years in order to obtain the same end, namely, that of passing through a cultural treatment before entering upon a technical and wrongly conceived non-cultural stage. In recent years too it has led to the unnecessary multiplication of engineering courses by the subdivision and extension of former courses and with the accompanying evils of early differentiation.

Also, the inducements which an engineering education has seemed to offer for a short cut to a lucrative profession, or at least a fairly good job, has reacted on the secondary schools and inoculated them with the same evils that possessed the college. The natural development of the ideals of engineering education in the preparatory school was through the manual training school which, however, has rapidly tended toward a highly specialized technical school of high-school grade having a great variety of technical subjects too frequently uncoördinated, and seldom articulated with the college or technical school, greatly to the discredit of the latter. Again, it has tended toward the industrial type of school, and while attempting to serve its original purpose has poorly served the industries.

From the foregoing you will observe that I am emphasizing three evils that appear to have grown out of engineering education: first, the unfortunate breach which developed between letters and applied science resulting from a failure on the part of teachers to appreciate the difference in methods necessary to approach the two classes of mind; secondly the undue importance ascribed to subject matter in colleges of letters and science; and thirdly, the great differentiation in subject matter toward which engineering schools have tended. But the three may be included in the one charge of failure to coöperate, to coördinate, to maintain unity.

The solution so commonly recommended and already alluded to is that of applying our present system to the attainment of this end by giving our engineering students a preliminary education in language and the humanities before subjecting them to the supposedly narrowing influences of the technicalities of professional study; to superimpose their professional work on a foundation consisting of a layer of preparatory study, later to be surmounted with successive layers of language, history, economics and other subjects not usually coördinated; or to extend their training by increasing the years alloted to college education, always in the belief that we are turning out a finished product. In that belief, too, we frequently revert to the methods employed in our youth, and to the experience of our fathers under the influence of the great educators of the past. We regret that the increased demand for education, and the machinery of education have made it impossible for the student to sit at the feet of the master and receive the direct influence of the refined and fully matured life, rich in the great truths which lie outside the text-book and the lecture-room. But it is useless to lament the changed conditions which make our ideals so difficult of attainment, even in the fast disappearing small college. The day of the educational trilogy of Mark Hopkins, the student and the log, has passed. But a great opportunity will be ours when we shall come to recognize that composite Mark Hopkins which can be created from the perfect coördination of the many minds of which our institutions are composed; when all these individual ideas shall cease to operate in their narrow and isolated channels and unite in the one great deep stream of intelligence flowing quietly in harmony to serve the highest ends of education. With the strength which lies in this sort of unity, the smallest and most meagerly equipped institution, even with mediocre teachers, may rival the most richly endowed and best equipped school, if the latter ignore the unity to be obtained by coördination. Without the unity which comes from coöperative work on the part of teachers and the realization of the true spirit of coördination, we shall make but slow progress in the bettering of our educational condition. Nor do I confine myself to a criticism of the college only, for this is equally true of all grades, and between all grades. It must operate to remove the artificial barriers which we have set up between the several grades; to abolish the abrupt transition between preparatory school and college, which surely cannot be justified by the statistics in the recent report of the Carnegie Foundation, in which we are informed that previous to admission but 55 per cent. of college students have attained the grade prescribed by our higher institutions of learning as "college grade." The courses of training in our English, classical and manual training schools should lead to the higher education, independent of the subjects taught, and dependent only on the character of the training. I would also include the commercial and industrial schools in this category, having no sympathy with, or belief in, the theory that a vocational selection can be made which shall determine at an immature age the unfitness of a youth for a higher education, shunting him into a special training which will debar him from higher schools. Specialized training at an immature age is narrowing to the community as well as to the individual and emphasizes the horizontal stratification of society. If there is a democracy in education it lies in the possibilities for the removal of a lad from the caste of his parents, his family, or his community and permits him to cherish and perhaps realize the ideals of the several strata of intellectual development. This was emphatically stated in a report by our Committee on Industrial Education, as follows: "In America all schooling should lead primarily to the elevation and development of the individual and only secondarily to a greater material prosperity." I am no advocate of lower standards for entrance to college, but I would never dam the streams which might flow there. Neither am I discouraging any form of vocational training that is properly coördinated with the high school or the college, save that which serves industrial interests only by raising a barrier to higher education.

As the several educational streams leading to the highest education should coördinate their courses with the local vocational interest, so should the technical school serve the interests of those students to whom a full course is not desirable, or possible, as well as those who may continue beyond the prescribed courses. There are many students who would profit greatly by two years of college work and who should be able to leave at the end of that time without a sense of failure or disgrace because of the incompleteness of their training. Moreover, the way should be made possible and attractive for a return to study whenever the conditions are favorable.

The courses in technical schools as well as in colleges have been, and are, too self-centered for the best results. This has been due somewhat to our inheritance of independent departmental work which has permitted and even encouraged isolated instruction in unrelated subjects, and frequently by those whose lives have been narrowed by too much specialization. The competition which has developed among the several departments of technical training has also led to that which seems to be an evil, namely, an attempt to teach too advanced subjects in the several departments, thus leading to an early specialization of courses.

The real measure of the development of a student cannot be accurately weighed in intellectual units. Acquaintance with subject matter does not serve to prove a man's fitness to serve his fellow men. Wisdom is a quality and not a quantity measure of mind. I welcome the realization by the Johns Hopkins University of a movement toward which I have aimed for more than a decade, namely, a general course for all engineering students continuing for three years and followed by one year of elective work of a special character. The marked differentiation between the courses in Mechanical and Electrical Engineering has not tended toward the making of better mechanical engineers or better electrical engineers. The divisions among the several departments of Civil Engineering have, I believe, been equally unfortunate. I go farther and deplore the great barriers which have been raised between civil and mechanical engineers in the four-year undergraduate course. My experience has led me to believe that many college students are unable to make a choice of professions at the end of two years, some are unable to choose wisely before the close of the third year, and some discover the error of their choice after graduation. This opinion is based on an experience with courses which for some years have permitted no differentiation before the junior year, and only a partial differentiation during that year. Hereafter the Mechanical and Electrical courses will be identical previous to the senior year.

But, the specialist exclaims, "How can I maintain the high reputation of my department unless the fundamentals are taught early in the course and the subject pursued continuously thereafter?" Possibly this may be difficult, but until one has coöperated with cognate departments and persuaded them to weave the thread of his specialty into the warp of other courses he does not know the possibilities open to him for lessening the prescribed time and perchance broadening the specialty. Of course he will be called upon to do the same for others, if the coöperative spirit prevails, and in so doing the influence of his own work may be greatly extended until he is surprised at the number of departments with which coordination may wisely be effected.

It was once regarded as an absurdity to attempt to establish intimate working relations between such departments as English and pattern making, or even for the department of English to have dealings with the Philistine of the Engineering School, save that necessary to the interests of humanity in exerting such an influence as might better his commercialized condition.

And yet I have seen these same student engineers win literary laurels in competition with their fellow students in "arts" courses by themes on the drama and art, and the writing of stories. This condition was not attained however until the English of the Engineering School was segregated from the arts course, and conducted by sympathetic instructors who studied the viewpoint of the engineering student and who finally coördinated their work with such departments as drawing, mechanic arts, physics and surveying.

But "Why should segregation be necessary?" I am frequently asked, "Are not the established departments in our arts course competent to conduct this work?" And my answer is, emphatically, "Yes, so far as the ability to supply all the required information is concerned; but no, when the necessary appreciation of the student point of view is concerned." The natural reasoning powers of the engineer, which we labor to develop, lead him to pass judgment on the usefulness of courses, and he is quick to condemn those studies which do not seem to be related to his major subject. Give him an appreciation of the truth concerning the importance of language, which engineering teachers have been all too slow in recognizing, and you will have no cause to lament his enthusiasm. He must be made to realize that all the technical knowledge of which he can possibly possess himself may be of little use unless he can avail himself of the avenues for marketing these products, and that the great trunk-line is his mother tongue. Then he will be as enthusiastic over his English as he is over his technical studies. He may also be taught to see that he cannot better develop his mother tongue than through the knowledge and practice of other languages. For this reason alone I believe in the requirement of at least one foreign language in a technical school, and much of one rather than a smattering of two or more.

But there is a by-product in this coördination of language and engineering which is generally lost sight of, namely, a love for literature and art such as this type of mind would not receive through another source. I have heard the greatest enthusiasm expressed for the study of such electives as the drama and Greek archaeology by senior engineers, and only because of the growth in appreciation due to the pursuit of language studies for engineering ends. I know this is a reversal of the "orthodox" cultural method but is it not the business of the educator to discover the means best suited to the end rather than to subject all types of mind to our stereotyped systems? Is it not our duty as educators to extend the vision of our pupils beyond the technical horizon; to open to them a vision of the fields of learning not included in their professional studies, and if this can be attained only by an inversion of pedagogical methods, shall we sacrifice our students to our methods? It is almost universal to order the courses of a dinner with the meats preceding the sweets and I tried to bring up a child under this régime only to learn later that I was violating the demands prescribed by nature, which required cake for the first course to insure a good relish for the meal; but, like most educators, I stuck to the system for a long time before submitting to such heresy as a "cake cocktail."

The opposition to the manual training idea, against which our lamented Calvin Woodward so valiantly and successfully fought, was an example of this persistence of the educator to perpetuate a long-established method instead of diagnosing the state of mind of the student. The failure to recognize the cultural value of engineering courses by scientific as well as classical teachers is due to the same cause. But how are we to diagnose these several phases of our educational malady and prescribe the correct treatment for all classes of students? I believe this can be accomplished only through coördination, and coördination means coöperation, and coöperation always implies some yielding of our supposed rights and pet ideals to others. This requires a love for the development of the individual student which is paramount to the maintenance of our own professional hobby.

It is the teacher and not the subject or the equipment of buildings and apparatus that makes the enduring institution; but until teaching is unified to a much greater degree we shall fail to attain that degree of educational efficiency which will enable us to reach the limit of our ideal.

Success in teaching is much less dependent on an exhaustive knowledge of a subject than on the ability to make a judicious application of the right quality and quantity. Profound learning should serve as a reservoir, the volume and head of which will command the respect of the student, but which requires great judgment to control, that it may not be turned on indiscriminately in such volume and pressure as to drown that which it was intended to nourish. It is much easier for the teacher to acquire the necessary knowledge for teaching than to properly dispense it, since to do the latter requires a knowledge of the individual which is rarely adequate to the needs. My experience leads me to believe that few instructors have the wisdom, the patience and the imagination necessary to diagnose properly the intellectual condition of a student. It is the highest test that can be applied to a teacher. The discovery of the cause for failure is often the work of an expert and should be the goal for which every teacher should strive, but by his unaided efforts the instructor is seldom equal to the task; he needs the example, the inspiration and the wisdom which come from coöperative work, as well as an understanding of his duty toward the individual. No successful teacher of engineering can live to himself within the cloistered walls of his own subject. Not only must he cooperate with his fellow teachers in coördinating his work with theirs, but he must feel the pulse of the world about him, and not only the engineering world but every noble life interest with which he can coöperate. It is my belief that the spirit of this influence is most needed to promote a greater degree of unity not only in engineering education, but in all education.

THE FINANCIAL MANAGEMENT OF A SCHOOL OR UNIVERSITY.

BY T. H. B. McKNIGHT,

Treasurer University of Pittsburgh and Treasurer Pennsylvania Lines West of Pittsburgh.

An educational institution of any kind is not primarily a business organization, its principal purpose, of course, being the training of the minds of the young for the greatest possible usefulness to themselves and their fellow men. To enable it, however, to carry out most efficiently and to the greatest extent the purpose for which it exists it must have a capable and careful business management in order to insure that the money which comes into its hands is administered wisely and without waste, and that as little of it as may be is diverted from its main object to the merely mechanical work of making the "wheels go 'round."

An educational institution, on its business side, is a corporation. It has its revenues to collect and administer and must pay its debts and live up to its contracts or it will soon find itself in trouble. To enable it to do these things well it should have a thoroughly good accounting system and should keep all its financial affairs absolutely straight and clean so as to get the best possible results out of its revenues and command the respect of the public.

It is the misfortune of most of our older schools that at the time of their beginnings their founders had not the most remote conception of what they would become in the course of time or how much growth might be expected, and, hence, should be allowed for. At the present time, we have a more far-reaching view, and plan our campus and buildings with clearer foresight of the thousands who will need to use them in the coming years. Financial management should begin with the choice of the location for the school, where it can be of the greatest use and where it can avail itself of the greatest aid of every kind. In the planning and placing of the buildings the financier will consider that modern business methods have no place for unused plant and will so arrange the buildings that they can be in use practically all the time and thus capital be conserved for producing income. Both room and buildings will be so much needed in the future that it can not be considered good finance to put up separate halls for subjects which only require a few hours of teaching a week. Probably the best results will be obtained from medium-sized buildings only far enough from each other to make it impossible that fire should communicate from one to another and near enough to be used interchangeably when advisable.

As, in the last analysis, the strength of any school is its teachers, who make it great by their abilities and their reputations, good financial management will prevent the available income being spread out too thin by the attempt to cover too wide a field, and will insist that the departments of study be limited to such as can be thoroughly taught by good teachers. To secure and hold the best teachers it is absolutely necessary that they be paid a sufficient sum to enable them to live comfortably and respectably, to rear their families as becomes their standing, and to lay aside something for the proverbial rainy day. Any less provision is unfair to the teaching force and will prevent the highest success of the school. Better, far better, have fewer professors to teach fewer subjects, but every one a master in his own line. The fame of the school that does this will soon go abroad in the land.

To go a little more into the detail the general subject may be divided into four heads:

1. General efficiency of administration.
2. Proper system of accounting.
3. Proper handling and investment of endowment funds.
4. Insurance and care of buildings.

These subjects will be considered briefly.

GENERAL EFFICIENCY OF ADMINISTRATION.

Whether the institution is large or small it should have an efficient business organization and should use the most approved methods.

A thoroughly careful and reliable secretary is an absolute necessity, and also a separate and independent auditor or accountant, reporting to and responsible to the board of trustees. The treasurer is not so important and need not necessarily give his whole time to the institution he serves in that capacity. A purchasing department which will buy all supplies on properly approved requisitions from the different divisions will be found very useful and will save a great deal of money. If this department also buys the books required by the students it can make a profit for the school and still save the students money.

The business management should extend to every one of the various activities of the institution and should see that they are carried on without unnecessary duplication of expense and without waste or extravagance or undue leniency to one department more than to another in the matter of spending money. Sometimes it may be wise to spend when the money is not in hand; at other times it may be wise to withhold it even when it is in the treasury.

As a rule every institution has demands in its proper line of work for many times the money that is available, and it requires the best of business acumen to decide between the rival claims and to spend the money that is to be had so that the greatest good for the whole institution may be achieved.

PROPER SYSTEM OF ACCOUNTING.

The keeping of the books is so important that it should be in the hands of an entirely capable man. In a general way each institution, no matter how many its departments, should have but one set of books, one general balance sheet and one income account, upon which should appear every financial transaction, and from which should be made each month a statement to show in a condensed form the exact condition of the institution.

The income account may be made to show separately the income and expenses of each different department. for careful watching and comparison of the figures, but the balance at the end will be the total for the whole institution.

The receipts from all the departments should go to one treasurer and into one common fund, and all expenses should be paid on vouchers originated and approved in the different departments but checked and audited by the accountant and paid by the treasurer out of the common fund. This avoids the embarrassing situation. which sometimes occurs when there are different depositories for the different departments, of one section of the institution having no money to pay salaries while another section is in funds. The necessity for borrowing money for current expenses is thus avoided unless it is really necessary for the institution as a whole.

To save needless clerical expense the most modern methods and most approved form of cash vouchers and other blanks should be put into use and the books should be thoroughly gone over and audited by an outside firm of chartered or public accountants who should make report to the board at the end of each fiscal year. This may seem an unnecessary expense, but it will be found to be money well expended and may prevent a scandal—for it is always opportunity that makes the thief.

For the same reason, and as a protection for the funds of the institution, the treasurer and all who handle money and the accountant who approves the vouchers for payment should be under bond with corporate surety.

Finally the published reports of the institution should be so clear and should show so much in detail its financial condition that everyone must have confidence in its soundness and the candor and honesty of its management. for its future progress depends upon its receiving money from its alumni and friends or from state governments, and the best way to bring such gifts is to show to everyone interested how carefully the money will be spent or invested for the good of the community.

Proper Handling and Investment of Endowment Funds.

The endowment fund is the means by which those who have fought their fight and passed over continue their influence and good work through the generations that follow them as far as our thoughts can reach, at least as long as the present social order stands. It stirs one's imaginations to remember what has been accomplished by some endowments given years ago and to think that when a man dies he may leave some of his money for which he worked so hard, to continue his work for him long after his body is in the dust. Not only so, but he knows that it will be doing the particular kind of work in which he was most interested, for he can leave it to be used as he wishes.

Where the officers of an institution are asked to suggest what form of endowment they would prefer to receive they will be wise to ask that the money be given them for "general endowment," for in the lapse of time the specific purposes for the furtherance of which money has been given sometimes become entirely useless owing to changing conditions, but the income of the general endowment fund will always be applicable to the greatest need at the time in the judgment of the trustees.

Investments should not be particularized or "ear-marked" as representing certain specific endowment funds but should be carried in one account representing all the endowment funds, specific as well as general. There is no possibility in this way that by an unfortunate investment a particular sum given by a friend of the institution may be lost. If, however, it is found that some of the investments have become worthless, or have depreciated in value, the general endowment fund should be reduced correspondingly, leaving the specific endowments undisturbed.

Probably the investments that yield the highest return consistent with safety are carefully placed first mortgages on residence property, but unless the institution has enough of them to compel it to adopt a system of watching them, as to payment of taxes, keeping up insurance and seeing that the property is kept in perfect order and that the district is not deteriorating, mortgages are really very unsafe, for the institution may have to take over the property for non-payment of interest at a higher price than it will realize at sale. Mortgages are also open to the objection that they run for comparatively short periods and at maturity the holder of the mortgage has the option to take his money at a time when it can not well be re-invested or to accept a reduction in interest. A mortgage never shows a profit, if there is any change in value it is for the worse.

For most institutions bonds of solvent and established corporations will be found a more satisfactory investment. There are so many of these to be had at reasonable rates of return that with careful selection on competent advice, and by dividing the money to be invested among a great many different kinds of bonds, the risk of loss is practically nothing.

If the bonds are wisely invested in the first instance the endowment fund may be increased by selling bonds that have increased in price and buying others of more recent issue to take their places. Standard bonds sell on a better basis after they have been out a few years and new issues, intrinsically just as sound, can be bought from original purchasers at considerably lower prices. By selling investment bonds that have appreciated in price and reinvesting the proceeds, several per cent. profit may be made on each transaction and the endowment fund largely increased in the course of a few years. The best way to do this would be to put a list of the bonds owned in the hands of an entirely reliable bond house and ask them to recommend changes when in their opinion they would be wise. As they will get commission both on the sales and purchases they will not overlook the matter.

An account should be opened on the books, "Profits on exchange of securities," and to this account should be credited all profits made in this way and to it should be charged any losses made in endowment investments. This account forms part of the endowment funds and is represented in the investments. When it gets larger than is necessary to protect against losses a round sum should be transferred to the "general endowment fund." An endowment fund carefully handled in this way should double in fifty years or less.

All bonds purchased above par should be amortized by charging an aliquot portion of the premium to "interest received" at each interest period or at least once a year. Bonds purchased below par should be carried at cost as long as held. In this way the investments are gradually getting better than cost and will show small profits at maturity if held that long.

All bonds that are registerable should be registered in the name of the institution as soon as received, and the securities should be kept in a safe deposit vault to which access may be had only by the treasurer when accompanied by some other officer to be specified in the by-laws. The by-laws should also provide that transfers must be executed by the president and the secretary with the seal and countersigned by the treasurer.

Endowment funds should not be invested in stocks of corporations, but especially not in bank stocks to which a liability is attached in case of failure. If stocks come to the institution by gift or bequest they should be disposed of as soon as possible.

INSURANCE AND CARE OF BUILDINGS.

Buildings, of course, should be of fireproof or at least of slow-burning construction and should be separated by a reasonable distance and not connected by roofs or colonnades of combustible material. The roofs should be of tile, slate or metal. With a group of buildings of reasonable size, say all under $250,000 in cost, built in this way the institution can afford to be its own insurer as it will get the benefit of average just as an insurance company. If, however, the buildings are surrounded closely by the houses of a city or are inflammable and close together it would not be safe to allow them to remain uninsured. If one of the buildings should be very large and expensive and not entirely fireproof it should be insured.

When it is decided that an institution has enough buildings well scattered for it to take the risk of fire it might be as well, when the payment of insurance premiums is discontinued, to pay the same amount each year into a special "insurance fund," the money so set aside to be invested and the interest compounded until there is enough money in the fund to erect a needed building, which may be considered as replacing a burnt building in advance. Thereafter the same thing may be continued or the credits to the insurance fund be then largely decreased.

Of course it will be a part of sound financial management to see that all buildings belonging to the institution are kept in good repair so that no deterioration shall occur, but that age shall be for them only like the gray hairs of a man found in the paths of righteousness, "an honor and a crown of glory." We see about us, here in Princeton, buildings that date back to the beginnings of the University and their age and quaintness but add to the veneration with which we behold them.

The financial management of an educational institution, while very important, is also rather technical and would make very dull hearing if prolonged. The above are only a few thoughts on the subject, some of which it is hoped may prove of value as suggestions to the very able men who are all over the land giving freely of their time to do the business part of college and university administration.

Discussion.

Dean Anthony: I regret that Mr. McKnight's paper could not have been addressed to a body of college trustees or to all the bodies of the trustees of the institutions represented here. However, I see in it a most valuable tract; one which I shall make good use of, and we can all use it to good purpose. We are to be congratulated in having this valuable information.

Professor D. C. Jackson: I was impressed with the remarks of Mr. McKnight in regard to the use of buildings. The financial affairs are for the attention of the treasurer, the financial committee and the auditing committee. If the faculty cannot rely upon these functionaries to do their duty, the university or college must fail. Mr. McKnight suggests that buildings be planned with respect to location and character so as to give continuous service.

In one sense I fully agree with him in that. It is a disgrace to the educational interests of this country that they have utilized their capital or their property so ineffectively. I do not refer to their productive endowments but to their fixed property. This has been largely due to the faculties and to individuals who have been reluctant to teach in accordance with suitable schedules. In other words, individual comfort has often been treated as more important than the financial condition of the institution.

On the other hand, we can go too far in the matter of using our buildings constantly. The problem is not how to secure continuous use of floor-space but how to obtain the highest efficiency in teaching. Now a room which is used two or three hours per day for five days a week for ten months in the year may be used far more advantageously for a specific purpose than if it were used ten hours a day for twelve months in the year. Consideration must be given to the teaching requirements in solving this problem. To secure the greatest efficiency, faculty and financial management must make and carry out their plans conjointly. There are indications on the horizon which show we are rapidly improving in this matter of coöperation.

I was led to make these remarks because of the apparent tendency to test the efficiency of educational institutions by the number of hours the floor-space is used. But there is another method of testing educational efficiency than by the value of the floor-space. The author brings out clearly that one can place an educational building on cheap ground and thus insure cheap floor-space, because the ground rent goes into the cost of the total structure. But the same sort of buildings may be placed on the same ground area elsewhere, and the usefulness of the structure much increased thereby, even though the number of hours of use of the rooms for teaching are the same in both cases.

These are problems which must be worked out in each institution, through coöperation of faculty and financial management.

Professor C. Frank Allen: It is unfortunately a necessity with educational institutions that they should have one or two large halls, which cannot be used continuously or ever to a large extent. In a way these are an extravagance. That feature should not be lost sight of entirely.

Mr. McKnight: If such rooms are necessary having them is not an extravagance.

Dean Bishop: That would come under the definition of a necessity recently given, using the dress suit as the basis of the argument. It was decided that if the dress suit was to be used once a month, it was a necessity. Similarly a room becomes a necessity when it is to be used with a certain frequency assuming that no other room will serve the purpose.

Mr. McKnight: It is only by considering all phases of a problem that we arrive at the correct solution. If cash for educational purposes is given outright the question is which would be better, to put it into buildings or into an endowment fund? One would naturally put up as good a building as required and invest the balance as an endowment fund. In cases where buildings were given for particular purposes, and where the demand for the buildings for the specified purposes is small it might be better to combine these buildings with others, or utilize other buildings which are needed only for part time.

Professor Hugo Diemer: The question of inter-departmental accounting comes to mind in this conection. To be just and fair to all each department needs a capable accountant to take care of such accounts. Some teachers may not agree with me, but I think that a clerk should be assigned to every department which does work for other departments. At the Pennsylvania State College we make an hourly charge for the use of our machinery and tools. I repeat that it is only fair that there should be a system of inter-departmental charges made, and if this involves clerical work, we should have clerks to do it.

Professor W. E. Mott: Another thing worthy of mention in this connection is the charging for the use of apparatus by instructors and others doing outside work. In some cases members of the teaching force carry on research work involving the use of apparatus and machinery and no charge is made to reimburse the institution for the deterioration of the equipment. It seems to me that there should be a system of uniform charges to cover this deterioration.

Dean Bishop: The Committee on College Administration last year made an investigation to ascertain the general practice along this line. We found that many of the schools were discussing the question of making a charge to professors for use of apparatus, ranging from ten to twenty per cent. of the total receipts from their research work.

THE RELATION OF THE ADMINISTRATIVE DEPARTMENT TO THE TEACHER.

BY C. R. MANN,

Associate Professor of Physics, University of Chicago.

It is quite a change to come from an atmosphere of ethereal vibrations and ionic charges to one of push and activity of this sort. I feel like the old darkey who said that when he was a boy they used to tell time by grandfather's clock which stood in the hall, ticking, "Never, Forever; Never, Forever"; while now they tell time by the Waterbury watch, which says, "Git thar! Git thar! Git thar!"

When it was suggested that I discuss the relation of the administrative department to teachers, I felt like the countryman when he first saw a hippopotamus. After looking at it for a few minutes he turned away, shook his head and said in disgust, "There ain't no such consarned thing!" My first conclusion was that there is at present no relation between college administration and teaching. I would like to raise the question: "Is this true, and if so, why?" As I look back to my own college days, I realize that I was not administered at all. At the present time students are administered a great deal, and I raise the question: "Is this an advance or not, and in what particular way?"

When we first entered college our entrance requirements were counted in such terms as four books of Cæsar, six books of Virgil, algebra through quadratics, plane geometry, etc. Those terms carried a certain content of achievement in them. Now the student's entrance requirements are counted in such terms as one unit of algebra, one unit of geometry, etc. The unit is defined in various ways. There was a national conference, composed of delegates from various associations, which attempted to define this unit. Their conclusion was that the unit was 120 60-minute hours of class work—not four books of Cæsar, and six of Virgil, but 120 60-minute hours of class work.

Having defined the unit in that way it becomes administrable under a system of book-keeping. Clerks can evaluate the certificate in minutes to determine if it is satisfactory. It is a method of measuring educational progress which might be applied to a case which recently came to my notice in the artistic field. There was a sign-painter who lived in the country and who spent his vacation in painting canvasses. After spending an enormous amount of time upon a canvas, he showed his work to a friend, who asked, "What is it?" He replied, "It is a portrait of my son." The friend's only comment was, "The only trouble is that it needs a second coat of paint on the hair." By the unit system this man would have received a higher rating than Sargent would get on one of his masterpieces.

The change in method of rating, in reference to entrance subjects, in terms of time instead of achievement, is a characteristic one which demands attention. The reason for this change is that the first system was not administrable, and the second is. Therefore, we have developed administrative dexterity and achieved a system which can be operated very easily in offices and by clerks.

The change began to take place about twenty-four years ago. In 1892 the committee of ten began to consider this subject, and made a preliminary examination of the curriculums of forty typical schools. They found that in these schools forty different subjects were actually being taught in forty different ways. That was an appalling discovery from the standpoint of administration. Whether or not the facts had any bearing on the problem of meeting varying local conditions and changing needs, the report stated that it was a horrible condition—which it was, from an administrative point of view. The committee set out to improve it and you know the result.

They selected twelve subjects which they declared were eminently proper for secondary schools. These subjects soon became the "Twelve Apostles of The Doctrine of Formal Discipline." They were arranged in groups and systems and tables, and any school could select one of these tables, pick out a curriculum and arrange a fitting system. The scheme had obvious practical advantages of that sort.

The effect of this system is interesting. The professor can count up the hours the student has put in and then the clerk in the office can tell whether the student is educated or not. A specific case recently came under my observation. A young man in Illinois attended one of the best high schools in the State, one where considerable emphasis was placed on scientific work. In the senior year a course in the management of electrical and other machines is given. This young man was very much interested in the course and passed it so successfully that immediately upon graduation he was offered a good position. He was able to use his skill and information in making a living, and succeeded also in setting aside enough money to take him to the State university, within a year and a half after graduation. He then applied for admission to the State university, which recognized all the units he had except the one on electrical engineering. That was a stranger to them, they could not accept it. They had never seen it or heard of it before and did not know what it meant. He was, therefore, admitted with a condition in one unit and he was refused credit for a study which enabled him to earn the money which made it possible for him to attend the university. That actual case is an effect of the administration system as it has developed. It illustrates the operation of the system from the viewpoint of the effect upon a student.

Let us consider on the other side the effect from the point-of-view of the faculty. We have all observed members of faculties in their meetings when the administration of the curriculum was under discussion. We have noted that, after the requirements of this, that or the other course had been seriously discussed and settled, the meeting adjourns and no further thought is given to the subject. It is not necessary, for the administrative system is so complete that when the faculty has once passed on a matter, the clerks in the dean's office can see the instructions are carried out.

I raise the question as to whether or not such a plan really accomplishes the desired results. A characteristic case is that of the modern languages, which has particularly troubled the medical men. The faculty decides that every doctor should read German; and they pass a resolution that no student shall be admitted to the medical school until he has had two, three or four units in German. Then the members of the faculty forget it and wonder why the student cannot read German when he graduates. The matter of ability on the part of the students to read German has been turned over to the administration officers, and we expect the student to be able to read German simply because it is in the requirements.

The same condition was illustrated recently in Chicago. It had been noticed that the candidates for the doctor's degree were rather deficient in the use of English. So the proposition was made that an efficiency test in English be made of all candidates for this degree before they were admitted. They would have to go in with the freshmen and show the English department they could write an English theme. The proposition was made seriously, but the faculty did not take it so; and, after discussion, the proposition was rejected. In this case the effect of this administrative system on the faculty is apparent, because it is evident that we are not going to get candidates for degrees with a command of German and English by passing resolutions. Training in language is too complicated; it is a matter of English diction and clear thinking. If the modern language and English departments wish efficient training in those languages, the way to get it is by giving the students who go out to teach in the elementary schools some idea of how those languages should be taught.

Now this is not being done at the present time. Fifty per cent. of the graduates of American colleges go into teaching. Few of these have received any professional instruction, or have any conception of what a school system is like and how school teaching can be carried on effectively. The young teacher goes out to teach and he does to those whom he teaches just what was done to him in college. In one of the country schools of the Western States, a teacher of botany had a class of fourteen real live boys and girls placed around the room on benches, each with one eye ''glued'' to a microscope. She walked behind them and read to them the notes she had made in her notebook in college. That is typical of what takes place everywhere. The departments do not lay special emphasis on methods of teaching. The members think that when they sit in faculty and decree the requirement of a given number of units that they will get the result which they are seeking.

I do not wish to convey the impression that administration is utterly useless. We realize it has a very important function and that the more efficient the administration, the more efficient the school will be. But we must not become blinded to the fact that at the present we have overestimated the efficiency of administration in education. We have come to rely on the administrative end of our work as the most powerful means of achieving educational results. Administration is necessary and it is very desirable to have it efficient. But administration at present seems to have the upper hand. You have all had experience with the ''Superintendents of Buildings and Grounds'' as the feudal lord of the campus. That is because administration is on top at the present time.

Now this ''administration on top at the present time'' merely means that we have been giving our best thought to the development of that system. Is it not time now to turn our attention to the development of the correlative side, the teaching side? There is one serious obstacle standing in the way of developing this side at the universities, namely, the fact that a man in the universities or in a college at the present time cannot receive any recognition unless he devotes his attention to problems other than those of teaching. Presidents and trustees of universities assure us that advancement will depend on one of three things. One of these is research, which we all recognize as important; the second is administration and administrative ability, also obviously valuable; and the third is good teaching. I have not observed any large number of universities giving suitable recognition to teaching and the study of teaching methods, the inter-relation of educational departments, and other such matters. I have not noted any specific instances where universities have recognized, by academic or other advancement, this particular form of activity.

This condition is not due to the desire on the part of the universities to slight the teaching function. They are sincere in stating that they are willing to recognize good teaching, but it is difficult to measure good teaching. Research work can be measured; a man produces so many pages a year which are printed and distributed among his colleagues, and are considered worth while. Similarly, if a man is a clerical administrator, runs his office well and extends the influence of the university in various ways, his worth is something easily measured. The administrative officers have a means of deciding whether he is worthy of promotion or not.

But, on the other hand, how are they going to measure good teaching? So far as I know no one knows just what the qualities of good teaching are, at least they do not know them in such a way that they can define them. This furnishes a good reason for the discussion and study of what constitutes good teaching. If we were able to explain more definitely to administrative officers and trustees what the qualities of good teaching are, they would not be slow to recognize it.

Something might be accomplished toward encouraging the teaching side if in each institution there should be a vice-president or a colleague of the president who would give his entire time to the study of teaching and educational problems. The president has no opportunity for such work, for he must be absorbed in financial and administrative problems. A special officer could encourage the study of teaching problems, and could associate with him at least one member from each educational department. This group could devote themselves to the study of teaching problems. If such an organization could be effected in a number of institutions, and these groups could work together, it is very certain that the teaching side of the schools could be developed rapidly. We have a very efficient administration system; we could develop an equally efficient teaching system; and then coördinate the two with the administration side as the servant of the teaching side. This would give us a better system, under which the pupils would get much less schooling with a great deal more education.

Discussion.

Professor C. M. Wirick: There is a body of men capable of passing on the qualifications of teachers. If this information could be obtained it seems that objection which Dr. Mann made would not stand. Every member of this Society knew as a student when he had a good teacher and when he did not.

Leaving out of consideration questions of definition and qualification, we knew and we know yet who the good teachers were. If some way should be found for getting this information then the student would grade his teachers rather than the reverse. Similarly, the faculty member might grade the men over him, and it would be a good thing all along the line. The use of such a plan might do away with some of the so-called "efficiency." A teacher in a certain university has the honorable title among the students of "Mutt Smith." I do not believe his influence can be of any value to the student body or to the institution or to anybody else.

We should get the opinions of students in this direction and use it, as they are the only ones qualified to pass on the qualifications of the teachers. We know that when we were students our opinions were worth more than those of the faculty.

I can second Dr. Mann's remarks in regard to the student who was conditioned in a unit of electrical work. I know of a case which occurred last year where a student went ahead handicapped by a "condition," and did the best work in the class. Although he is now employed by the Bureau of Standards, he is still conditioned on that particular branch.

Professor A. E. Flowers: I am interested in what Dr. Mann said about the measuring of teaching abilities. The suggestion made by Professor Wirick can probably be carried out best through the alumni. Students do measure the ability of their teachers, but I am not sure that their estimates as undergraduates are accurate. After they have been out a year or two their judgment is better. Dr. Mann, in commenting upon the efficiency of the present methods of administration, proposes additional administrative methods. He suggests for each institution a vice-president, whose prime duty would be to improve teaching efficiency. Now is that the best way in which to get what we want? Possibly we have in our present deans, administrative officers whose duties should be to a large extent to study the teaching qualifications of the men of the several departments of their schools.

There is another method which might be used to improve teaching efficiency. College faculties are at present devoting their time too largely to the discussion of such matters as the wording of by-laws and methods of administration while the educational problems, policy and the training of their own members are slighted. It would be possible to really develop educational methods in the faculties. There may be some hope also that our schools of education will emphasize the needs for training in teaching. Some day some of the schools which devote themselves to graduate work, will make it possible for those interested in research and teaching and in anything that makes for advancement of the university to take "advanced work" at a time when the teachers are free, that is, during the summer.

Professor W. A. Hedrick: The suggestion applies more to the secondary schools. if reports be secured from the parents stating the parents' estimates of the teacher. Have the parent report to the teacher the number of hours spent in study at home and the facilities afforded at home for study.

Professor G. R. Chatburn: The educational pendulum now seems to be swinging in the direction of a more careful consideration of the character of the teaching. In the past we have usually selected from among our students the bright ones for positions as "assistant." We have taken the man who made the highest class record, or the keen and bright student. As a matter of fact, the student brightest in his class-work is not always the best teacher. I have in mind a teacher of mathematics who, while scholarly, could not be called brilliant, but the alumni who studied with him "swear by him." In the same department was an unusually brilliant mathematician who could see through a long equation at a glance, who, in his explanations, jumped over several equations at a time, but somewhow his students were not enamored of him and his methods.

In the University of Nebraska, we are endeavoring to secure administrative results to the extent of requiring our teachers to state, in connection with each course of instruction, the amount of credit to be given for that course, how much of the work is given in the class-room, and how much time should be spent in outside study. Some of our professors said that they could not conduct their courses if held to a requirement of but two hours of a student's time for every hour of credit given. Some were requiring from five to seven hours. On the other hand the teachers who were less particular about work to be done outside the class-room, could not get any outside work done. In order to insure an equitable distribution of the student's time there must come the practice of regulating not only the number of hours of work done in the class-room, but also the number of hours outside the class-room.

Dean A. H. Fuller: Dr. Mann has given us a graphic picture of the need for more attention to the principles of teaching, and we shall look to him to go farther and state how his suggestions can be carried out. Good returns may be expected from a tactful application of administration methods to teaching. This should be accompanied, I believe, by careful consideration of the fundamental principles of pedagogy.

Two years ago, one of the instructors in the University of Washington took an undergraduate course in the Department of Education. Last year another man of professorial rank took an undergraduate course in education. Both claim that the fundamentals of teaching they received have helped them in their work; that they are able to get the viewpoint of the student better than they were when studying educational problems independently. One of the teacher's difficulties is to get his students to study efficiently and to think accurately. The educational courses helped our teachers in those directions.

Last year two of our students failed in a certain course in mechanics. Both repeated the course this year. One did very poorly in it again, but the other who took a course in education, parallel with the one in mechanics, did excellent work. In the educational course he was taught how to study, and was thus started on the right track. It seems to me that one step toward the solution of our pedagogical problems is to keep closely in touch with the departments of education.

Professor L. P. Breckenridge: There are two methods of making good teachers: First, to select the best teacher in a faculty group, and have him tell the others the secrets of his success; secondly, the teachers in every department should get together from time to time to discuss methods of teaching the courses in that department.

Professor Edgar Marburg: In the field of engineering instruction it is peculiarly difficult to secure teaching material of the right quality in the lower ranks, or to develop such material, because of the well-known fact that few of those appointed to subordinate teaching positions have serious expectations of following teaching as their life work. They realize, too, that, generally speaking, before they can hope to qualify for the higher positions they must win their spurs in practice in some one or more engineering specialties. Again, a young man who relinquishes a teaching position with a view of going into practice for an indefinite period and then returning to teaching, is apt either to remain in practice through preference, or, if he should retain his taste for teaching, to find difficulty in securing at the right time a suitable opening at a sufficiently attractive salary.

In addition to these conditions, which apply with peculiar force to engineering teaching as distinguished from teaching in many other branches, there are other difficulties from which, perhaps, no department of teaching is exempt, such as the inadequacy of salaries, and the scarcity of available men who combine teaching qualifications of a high order with other necessary or desirable personal and intellectual qualities. In a large sense it is as true of the teacher as of the artist, that he is born and not made.

I often feel that in the discussion of topics relating to education, one is apt to translate himself unconsciously into an unreal, or at least a somewhat idealized environment. As a practical matter, every executive officer finds himself hemmed in by more or less rigid conditions with which he must reckon. Compromises have everywhere to be struck. One of the most trying tasks which an executive may find himself obliged to face, is to say to a teacher of some maturity that he does not come up to the requisite standard. In such matters, full weight should, in fairness, be given to the human element. There are probably few here who are not conscious of having sat at times under teachers who, though perhaps poorly qualified as teachers in the narrow sense, were men of such lofty character, of such breadth of interests, of such friendliness and depth of understanding in their relations to young men, or were possessed of such other attributes—real though difficult to define—that their elimination from the faculty on account of inferior teaching qualifications would have been a serious loss.

In my judgment there is no need of any artificial system to determine whether the qualifications of a teacher are good, bad or indifferent. Every man who stands in a responsible executive or administrative relation to a department of teaching, knows, or should know, the strong and weak points of every member of the faculty.

It is not to be expected, even under the most favoring circumstances, that a faculty can be formed or maintained in which every element is of the ideal kind. An attempt to strengthen a faculty by a ruthless process of elimination is apt to work grave injustice and in the end to defeat its own purpose, through the introduction of inharmonious elements and the creation of an atmosphere of unrest and distrust.

Professor A. H. Robinson: It seems to me that this is the dawn of a new era. We have, as engineering teachers, gone into teaching without reference to pedagogy at all. Eighteen years ago the instructor at the summer school of Clark University was largely pedagogical. While I was in attendance at this school Dr. Hall asked me what I was teaching. When I told him that I was teaching mechanical engineering, he asked me what I was doing there. I felt like an outcast studying with people who were taking "child study" and subjects of that kind. I felt, however, that, as I was teaching, I needed to know something about the methods of teaching. As I have come into contact with teachers, I find that few of them know how to teach. For this reason I believe that such discussions as we are having indicate a new era of efficiency in teaching. Similarly, our students must be taught to study. We must put them where they can learn to study, and do away with our rigid course if necessary to secure the best results in this direction.

Professor C. F. Scott: In teaching there are the two fundamental things; the subject and the student. We must have great respect for the subject, and desire to present it logically and completely; but there is danger that we may not see it from the student's point-of-view. Some text-books are beautiful in typography but they do not present the subjects which they cover in a way that reaches the student. I heard considerable criticism of a certain text-book, so I looked over a copy and at first sight it appeared to be first-rate, with various topics apparently well presented in logical order. After my opinions in the matter had crystallized, I realized that there was nothing human about the book. It was abstract; there was no personal interest in it for the student. It was like a dictionary.

After one has taught a given subject it is well to look over the examination papers to see how effectively he has presented it. I have also on several occasions asked members of the graduation class to comment on the course which they had followed and to state wherein it could be improved. They have responded freely, and have given useful hints from their standpoint.

In one course that I find valuable to the students, we meet once a week for general discussion. The students prepare papers and take part in the discussion. They preside and record the minutes just as they would in an engineering society.

These are small matters in the problem of getting the student to take an interest in his course, but they are important. When you ask engineers what a graduate ought to be they say, "We want a man who can turn his hand to anything and do it, a man of training and ability and initiative." When we examine most of our methods and the habits which the students are acquiring, we find that they are often not developing those qualities which are wanted afterwards.

Dean C. Russ Richards: It seems to me that officers of administration should consider their principal function to be the promotion of the work of the teachers. We spend many hours in faculty meetings framing rules of administration. We spend an equal number of hours in efforts to waive those rules when a student wants a change. We are compelled to spend a great deal of time in writing more or less useless reports on all sorts of subjects. By the time that we have finished this sort of work we have little energy left for teaching or for the student. I wish that we could get a simpler system of administration details.

In one institution, a few years ago, the faculty spent a lot of time in revising the courses in engineering. After the faculty had worked out a new curriculum, a report was sent to the council of administration. This council considered it "an extremely important subject," and, since there was no time then for its consideration, held it up for six months. At last the council made a decision but this was not final. The report went to the university senate, which spent more time upon it. This senate has a committee upon "educational policy," to which the report was next referred. After three months it was reported back to the senate, where it remained three months more. The courses are not yet in operation. There is danger that administrative machinery may become so cumbersome as to impede rather than promote efficiency in teaching.

Professor Vladimir Karapetoff: Dr. Mann's address, strictly speaking, deals not so much with making individuals into good teachers, but treats of the way in which good teaching may be achieved in an administrative way. There are two conditions which must be considered in this connection. An institution can engage a teacher, assign certain duties to him, and leave him through his own inspiration and competency to do the best he can. This is, I think, the only possible way in smaller institutions.

In larger institutions, where there are a number of teachers teaching the same or correlated subjects, where there are beginners and more experienced men, some kind of organization in the department is necessary. While listening to Dr. Mann's address I asked myself just what kind of organization within a department is the best to improve the quality of teaching. Could not a considerable amount of work be done to establish the missing link between teaching and administration?

Whenever a question of organization comes up, a military organization is the first one thought of. The military organization was the prototype of all organizations, as it is the oldest type of human activity on a large scale, and the one which claims the greatest achievements during thousands of years. In such an organization there are three things, discipline, inspiration and system. There may be others, but these are fundamental. In the engineering department the same three elements should be looked after wherever there are three or more teachers teaching in the same line. Coxey's army, that wanted to march on to Washington, had plenty of inspiration but no discipline. The Roman army had plenty of discipline but no inspiration when it marched against the Germans and it was defeated.

We can not make a good teacher out of a poor teacher, but when one is associated with inexperienced but well-meaning men, he can help them by assisting them with his own experience. The discipline, however, must to a large extent be self-imposed. The associated teachers agree upon the best system of conducting a course, and then it becomes a self-imposed discipline to administer it.

Inspiration is something without which an army cannot be led to victory, and without which no department can do effective work. There is one kind of inspiration that is quite effective, namely, a tradition in the department *that poor teaching is something so disgraceful that it cannot be tolerated.* A rough soldier may be a thief and a marauder, but bravery is a tradition to him. He will commit most any crime, but to run away from an enemy would be a tremendous disgrace to him. If in a department the "tradition" is created that it would be a disgrace to have a student say, "I do not understand what you are talking about," or to have a teacher depart from a schedule without a good cause, we would soon realize a state of affairs more effective than many cumbersome rules and regulations could accomplish.

Dr. C. R. Mann: In closing this discussion I merely want to emphasize what Professor Jackson has told you with reference to the work the committee is undertaking, and my relation to it.

It is desirable that no one should get the idea that we are undertaking the study of the engineering schools of the country for the purpose of criticizing them or of finding out which are poor, and which are good schools. My function is to coöperate with you and to coördinate what this Society has been doing during twenty years or more. I want all the information that you have, particularly if you have been making special studies among yourselves.

EDUCATION IN SCIENTIFIC MANAGEMENT.

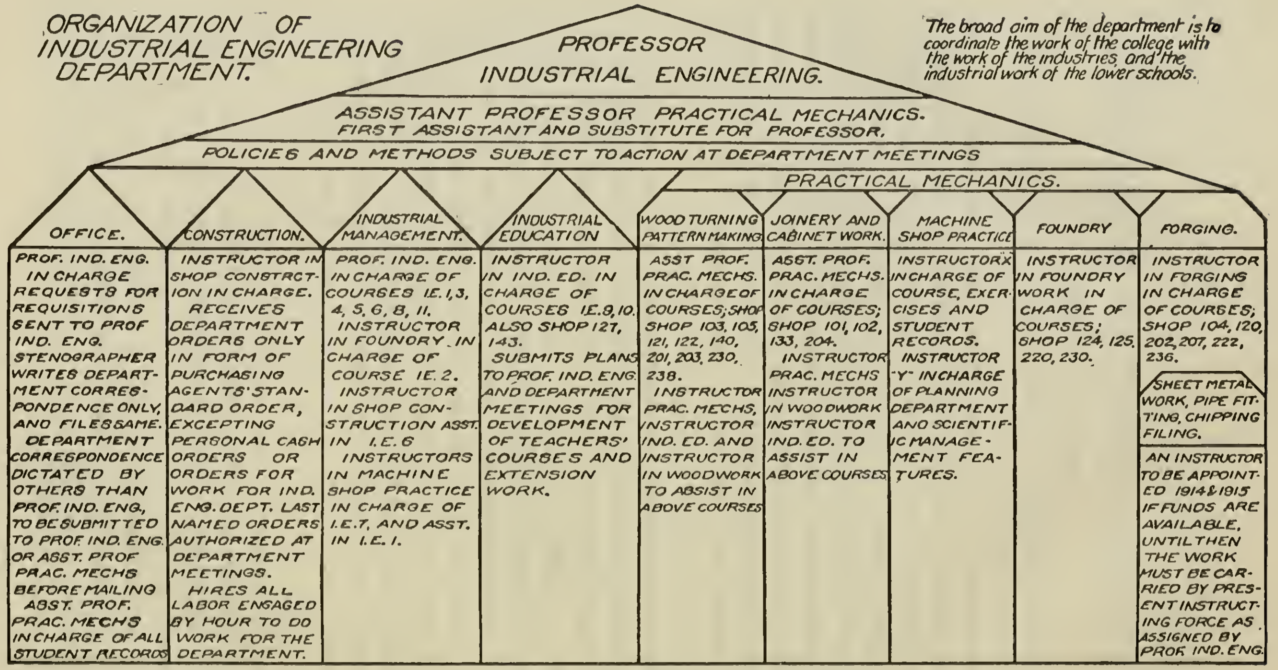
BY HUGO DIEMER,

Professor of Industrial Engineering, Pennsylvania State College.

Education in the principles of scientific management, in applied methods of scientific management, in allied or related arts and sciences, or in all of the foregoing, is being offered at the present time by corporation schools, correspondence schools, secondary schools, undergraduate schools of collegiate grade, and graduate schools. Moreover in many schools where there has been no direct formal teaching of the principles or applied methods of scientific management, these principles and methods have been utilized in the work of the class-room, the laboratory, or the shop, by men in charge.

There is a constantly increasing number of individuals who have pursued a course of some kind or another either in scientific management or in matters which in their opinion are equivalent, sufficient to justify them in their own minds in either assuming the title of efficiency engineer, industrial engineer or efficiency expert, or at least in assuming the ability to do the work ordinarily undertaken by those who call themselves by these titles. It would be unfair to accuse these individuals of misrepresentation because we have not as yet any authorized standards by which to measure the preparation, experience and ability of those who are licensed to use these titles.

There is no clearly defined meaning attached to the words "course of study," so that when we speak of a course in scientific management, unless we explain ourselves more fully, our hearers do not know whether we refer to a course of reading, a course of an hour or two a week for half a school year, or an extended series of studies representing four years more of specialized collegiate work with a preparation of twelve years preliminary schooling.


ORGANIZATION OF INDUSTRIAL ENGINEERING DEPARTMENT.
PROFESSOR INDUSTRIAL ENGINEERING.
ASSISTANT PROFESSOR PRACTICAL MECHANICS.
FIRST ASSISTANT AND SUBSTITUTE FOR PROFESSOR.
POLICIES AND METHODS SUBJECT TO ACTION AT DEPARTMENT MEETINGS
PRACTICAL MECHANICS.

The broad aim of the department is to coordinate the work of the college with the work of the industries, and the industrial work of the lower schools.

OFFICE.	CONSTRUCTION.	INDUSTRIAL MANAGEMENT.	INDUSTRIAL EDUCATION	WOOD TURNING PATTERN MAKING	JOINERY AND CABINET WORK.	MACHINE SHOP PRACTICE	FOUNDRY	FORGING.
PROF. IND. ENG. IN CHARGE REQUESTS FOR REQUISITIONS SENT TO PROF IND. ENG. STENOGRAPHER WRITES DEPARTMENT CORRESPONDENCE ONLY, AND FILES SAME. DEPARTMENT CORRESPONDENCE DICTATED BY OTHERS THAN PROF. IND. ENG., TO BE SUBMITTED TO PROF. IND. ENG. OR ASST. PROF PRAC. MECHS BEFORE MAILING ASST. PROF. PRAC. MECHS IN CHARGE OF ALL STUDENT RECORDS	INSTRUCTOR IN SHOP CONSTRCTION IN CHARGE. RECEIVES DEPARTMENT ORDERS ONLY IN FORM OF PURCHASING AGENTS' STANDARD ORDER, EXCEPTING PERSONAL CASH ORDERS OR ORDERS FOR WORK FOR IND. ENG. DEPT. LAST NAMED ORDERS AUTHORIZED AT DEPARTMENT MEETINGS. HIRES ALL LABOR ENGAGED BY HOUR TO DO WORK FOR THE DEPARTMENT.	PROF. IND. ENG. IN CHARGE OF COURSES I.E. 1, 3, 4, 5, 6, 8, 11. INSTRUCTOR IN FOUNDRY IN CHARGE OF COURSE I.E. 2. INSTRUCTOR IN SHOP CONSTRUCTION ASST. IN I.E. 6 INSTRUCTORS IN MACHINE SHOP PRACTICE IN CHARGE OF I.E. 7, AND ASST. IN I.E. 1.	INSTRUCTOR IN IND. ED. IN CHARGE OF COURSES I.E. 9, 10. ALSO SHOP 127, 143. SUBMITS PLANS TO PROF. IND. ENG. AND DEPARTMENT MEETINGS FOR DEVELOPMENT OF TEACHERS' COURSES AND EXTENSION WORK.	ASST PROF. PRAC. MECHS. IN CHARGE OF COURSES; SHOP 103, 105, 121, 122, 140, 201, 203, 230, 238. INSTRUCTOR PRAC. MECHS, INSTRUCTOR IND. ED. AND INSTRUCTOR IN WOODWORK TO ASSIST IN ABOVE COURSES	ASST. PROF. PRAC. MECHS. IN CHARGE OF COURSES; SHOP 101, 102, 133, 204. INSTRUCTOR PRAC. MECHS INSTRUCTOR IN WOODWORK INSTRUCTOR IND. ED. TO ASSIST IN ABOVE COURSES	INSTRUCTOR X IN CHARGE OF COURSE, EXERCISES AND STUDENT RECORDS. INSTRUCTOR "Y" IN CHARGE OF PLANNING DEPARTMENT AND SCIENTIFIC MANAGEMENT FEATURES.	INSTRUCTOR IN FOUNDRY WORK IN CHARGE OF COURSES; SHOP 124, 125, 220, 230.	INSTRUCTOR IN FORGING IN CHARGE OF COURSES; SHOP 104, 120, 202, 207, 222, 236. SHEET METAL WORK, PIPE FITTING, CHIPPING FILING. AN INSTRUCTOR TO BE APPOINTED 1914 & 1915 IF FUNDS ARE AVAILABLE, UNTIL THEN THE WORK MUST BE CARRIED BY PRESENT INSTRUCTING FORCE AS ASSIGNED BY PROF. IND. ENG.

Fig. 1. Organization Chart for Department.

I do not by these remarks wish to belittle the work done by institutions doing work of a nature which in educational language is termed extension or continuation work. Our large educational institutions might well copy some of the methods of the corporation schools. This is especially true of the time devoted to their work by the directors of corporation schools as compared to the time devoted to their duties and the fitness for such duties of the trustees or directors of large colleges. Take for example the Westinghouse Electric & Manufacturing Company's schools. The policies and methods of these schools are controlled by a board having representatives from the manufacturing, the engineering, and the commercial divisions. I meet one or more of these representatives, besides members of the teaching staff, at every prominent engineering and educational convention which I attend. They are present at conventions of the national engineering societies, at the foundrymen's and metal trades manufacturers' conventions, at general educational gatherings, at state societies of manual arts, at social and economic gatherings, in fact everywhere where they can gain inspiration and new ideas. A member of the board was sent to Europe to study foreign methods of industrial education and corporation schools.

The shop apprentices who are receiving continuation school instruction are given questions and problems relating to the company's payroll and wage system, stores accounting system, etc., so that they understand them thoroughly. The college graduates receiving the special course for such men are given a broader instruction. For instance in the matter of wage systems they are shown blue-prints of curves and charts comparing practically all existing methods of remunerating labor, and are told why the company has selected the type of remuneration in each of the various departments, which is at present used. The Western Electric Company also gives excellent training to the college graduates whom they employ. It offers distinct courses of preparation for the commercial and selling division, for the technical engineering division, and for the manufacturing and works management division.

A large number of persons are being reached by education of the extension type offered by the various private correspondence schools. Training in scientific management is being offered by three types of correspondence schools; (*a*) The large correspondence schools which offer courses in diversified branches of sciences, trades, and arts such as the International and the American Schools of Correspondence, (*b*) the correspondence schools specializing in legal and commercial training, such as the Alexander Hamilton Institute and the LaSalle Extension University, (*c*) the specialized correspondence schools such as those organized by Harrington Emerson, Clinton Wood, and George F. Card.

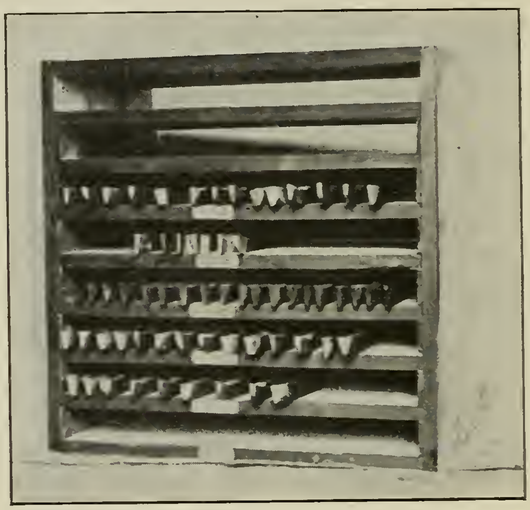


Fig. 2. Filler for Standard Tool-room Bin.

To the work of these institutions must be added the extension work of the various local Y. M. C. A.'s aided by the International Y. M. C. A. and the extension classes supervised by extension instructors from state educational institutions such as the University of Wisconsin and the Pennsylvania State College.

The work of the correspondence schools has been principally along the lines of principles of organization and management, commerce and finance, general accounting and manufacturing systems. The engineering features of industrial management are not as a rule included in the courses of instruction offered. Some of the monographs of these correspondence schools are excellent texts worthy of adoption in college work, and several of the correspondence schools have been sufficiently farsighted to permit the use of their texts by college instructors.

In secondary schools, otherwise known as public high schools, we find that scientific management is being adopted in some phases of manual training instruction. Several years ago I mentioned the use of applied methods of scientific management in a brief contribution to a publication circulating among manual training high schools, and received a number of inquiries from directors of manual arts for further information. There is no reason why certain principles of time and motion study, stores accounting, tool lists and tool-room methods, order of work and dispatching cannot be applied to this work, in manual training high schools along the lines we are following in our college shops.

When we come to consider the teaching of scientific management in educational institutions of collegiate grade, we will have to classify these institutions. In this group we have: (*a*) the classical or liberal arts traditional college intended as preparation for a course in a graduate school, (*b*) the college which aims to combine liberal arts with technology in a four-year course, and (*c*) the graduate school.

So far as the teaching of principles of management in the traditional college course is concerned, it will suffice to say that three hours per week in the senior year might advantageously be devoted to such subjects as economics of business during one semester, and organization and management in another semester; these subjects being taught by members of the department of economics, using such texts as Brisco's "Economics of Business" and Galloway's "Organization and Management." In colleges of this type we cannot expect the professors to have had practical experience in management, as the authorities usually prefer a man with a doctor's degree and no practical experience to a man with only a bachelor's degree and practical experience. More than likely, too, the professor will have to cover a wide range of branches in the field of economics such as political parties, labor problems, international law, principles of economics, etc.

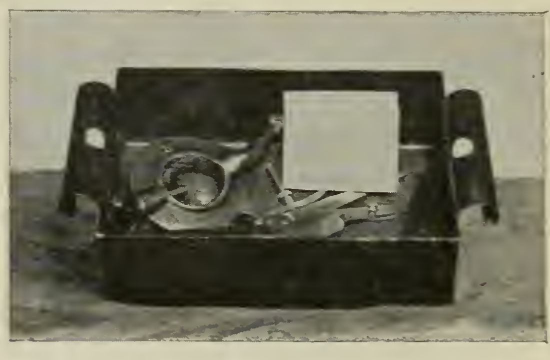


Fig. 3. Tote Box with Standard Set of Tools and Tool List.

Coming next to the college which aims in a four-year undergraduate course to combine some instruction in liberal arts with a course in technology, we have two types of college course in which attempts are being made to teach scientific management, namely colleges offering courses in commerce and finance or business administration on the one hand, and colleges offering courses in industrial engineering or business engineering or general engineering, on the other hand.

SCIENTIFIC MANAGEMENT INSTRUCTION IN UNDER-GRADUATE COURSES.

In the better grade of colleges offering courses in commerce and finance, and business administration the men teaching accountancy, money and banking, brokerage, and insurance are usually accorded professorial rank and salary and are, as a rule, men who have had actual practical experience in these fields. In these colleges, the teaching of management has been introduced as a sort of after-thought or recent development, largely as a result of what might be called the efficiency movement of 1911, which was chiefly due to the widespread publicity given to Mr. Brandeis's utilizing the testimony of prominent engineers who had been instrumental in developing the modern science of industrial management, in the hearings before the Interstate Commerce Commission. In many of these colleges the teaching of management has been handed over to young men of instructor's rank, with little practical experience and no executive experience in industrial administration. In some cases this instructor acts as a guide to students who visit industrial establishments having a reputation for good management and acts also as manager of a series of lectures to be given to students by well-known business managers and industrial and efficiency engineers.

The graduates of schools of this type are usually well grounded in theory of accounts and economics of commerce. Many of them are eligible, after some years of experience after graduation, to take an examination for the degree of certified public accountant. None of them are eligible to the title of industrial engineer or efficiency engineer, since they have not been trained in the fundamentals of engineering and have not had the engineering experience which alone entitles the graduate of an engineering college, after he has received his bachelor's degree and has had practical work for three years, to present a thesis and become a candidate for an engineering degree.

Coming to the undergraduate college courses in engineering, we need mention only in a passing way the "orthodox" courses in civil, mechanical and electrical engineering. The teaching of management in courses of this type is usually restricted to a one-hour-per-week course in the second semester of the senior year.

In some institutions such, for example, as the University of Illinois, where the control of the shops is vested in a distinct department, headed by a man of broad education and experience, and receiving a salary higher than the average professor's salary in other institutions, a necessary inducement to secure this type of man, we see certain applied methods of management embodied in the shop instruction given to students taking the traditional engineering courses, and in this way they get some contact with modern management methods.

We must bear in mind, however, that approximately 40 per cent. of the membership of the American Society of Civil Engineers consists of men engaged as executives in manufacturing or contracting work or in business for themselves as consulting engineers; about 50 per cent of the membership of the American Institute of Electrical Engineers comes under this class, and about 60 per cent of the membership of the American Society of Mechanical Engineers belongs to this group. We must also bear in mind that pretty nearly all of the best

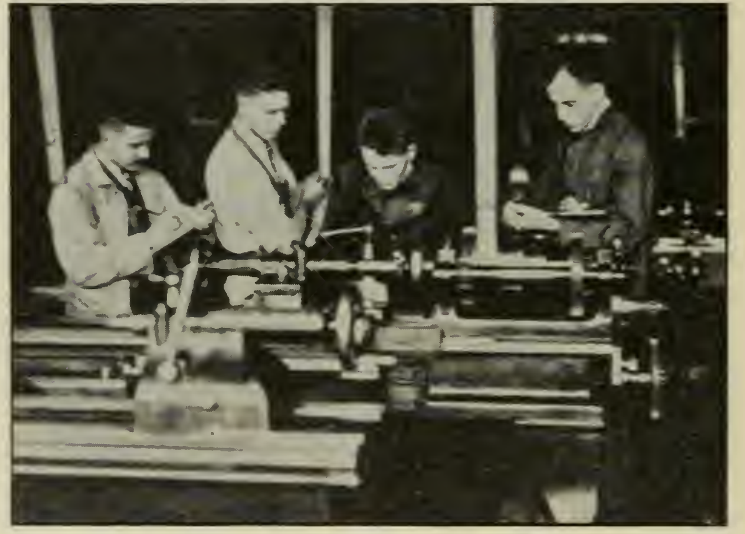


Fig. 4. Students Taking Time-Study Observations.

literature and noteworthy practical work in scientific management has been the work of engineers with no other direct training for management than their actual contact with men, machinery, methods, markets and money.

THE PROBLEM OF PREPARING YOUNG MEN FOR MANAGEMENT WORK.

It is very apparent to engineers who have achieved success in management that the average graduate from a school of engineering is confronted less often by problems requiring ability as an inventor than he is by problems requiring familiarity with principles and applied methods of industrial management. Young men who have completed undergraduate courses in business administration or in commerce and finance may be well grounded in sciences and arts relating to men, markets and money; but machinery, methods of production, and the lay-out and service equipment of industrial plants are engineering features of industrial management so interwoven with the human and economic and financial features as to make it a matter of grave doubt whether the industrial field is a fit one for young men who have completed only an undergraduate course in business administration or commerce and finance. In my own practical experience in installing methods of modern management in large manufacturing establishments in Cincinnati, Indianapolis and Chicago I have had occasion to place side by side young college graduates from various institutions and graduating from courses in business administration on the one hand and in engineering on the other. I have found that the engineering graduates were as a rule unfamiliar with business practice, accounting and economics, while the business administration graduates were ignorant of manufacturing and engineering, and were inclined to be insufficiently interested in the faithful plugging type of task assigned to young men of all classes. The engineering course men were usually the only ones who could be assigned to time study, and planning department work. The business administration men usually were able to handle work in connection with employment and welfare problems, and statistics.

Course in Management at Pennsylvania State College.

Eleven years ago, at a convention of the Society for Promotion of Engineering Education I presented a paper on the subject of "Education for Factory Management" in which I advocated the teaching of principles and applied methods of management in an engineering course. It was evident from the discussions of this and subsequent papers along the same line that the only manner in which training in management could be given in undergraduate engineering courses was through the medium of an entirely new course in which economics, psychology, principles and applied methods of management took the place of some of the more technical features of the designing and testing of the existing engineering courses. In 1909 we established our four-year course in industrial engineering at the Pennsylvania State College along these lines. This course contains all the fundamental mathematics, underlying science and mechanics given in the standard engineering courses, but in place of the more technical work in designing and testing we introduced work in organization, management, theory of accounts, factory accounting, foundry and pattern-shop methods and organization, machine-shop methods and organization, factory lay-out and design and the application of such methods of scientific management, as planning department including orders of work bulletining, making of time studies, preparation of instruction cards and tool lists, keeping of cost records and accounts on commercial work actually sold on the one hand and certain essential exercise work on the other hand. The degree obtained by students graduating in this course is that of Bachelor of Science in Industrial Engineering.

Training for Teaching Management.

When I was given jurisdiction over this course I felt that my experience as an engineer, superintendent, and consulting expert, while all very well from a practical standpoint, might still leave something to be desired for in the way of theoretical training. Hence, I voluntarily undertook to attend, as a regular student, the classes and examinations necessary for an undergraduate degree in history, economics and political science, taking such general liberal arts course as psychology, logic, and all of the course in theory of education offered at the Pennsylvania State College. I deliberately subjected myself to the drill and discipline of this undergraduate work because I wanted to secure anything that the graduate of a course of this type might have which was not obtained by an engineering graduate. I heartily enjoyed this work and only wish that all engineers could take work of this character. I am still more powerfully convinced as a result of taking this course, however, that even the most inspiring instructor, possessing the benefit of the doctor's degree and extensive foreign travel, but without experience in industrial management, cannot take the place of the trained and experienced engineer in teaching management. From a cultural and

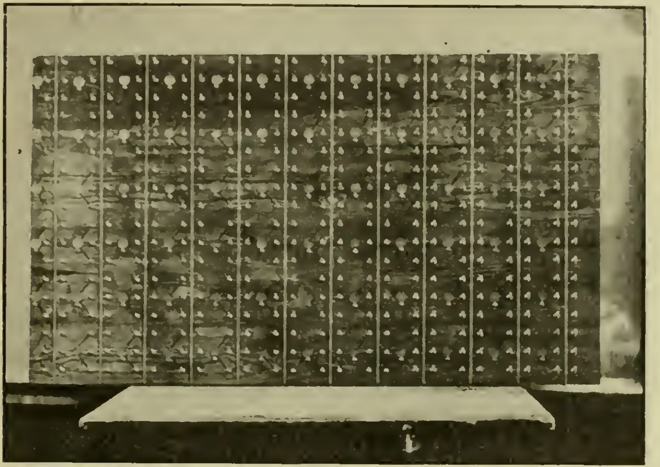


Fig. 5. Office Bulletin Board.

scholastic standpoint the practicing engineer has gained something quite as important and of totally different character than the liberal arts graduate with his Ph.D. and foreign travel.

For these reasons I do not believe in a graduate course devoted exclusively to technical engineering in a graduate school in which the engineering professors are technical experts and in which there are no experienced engineers teaching management. This teaching in industrial management cannot be given by classicists in undergraduate or graduate colleges of business administration in a manner which will meet the needs of the industries.

Graduate Schools of Business Administration.

These considerations bring us to the graduate schools of engineering and business administration. So far as concerns graduate school courses in insurance, transportation, salesmanship, accountancy, consular service and diplomacy, the standard undergraduate college course constitutes a suitable preparation. When it comes to a graduate course in industrial engineering, however, the undergraduate college course is, figuratively speaking, a wall or dam between the high-school training and the final training. In order to prepare for a graduate course in industrial engineering, there should be a continuous and widening stream of technology right through the undergraduate college course. No such opportunity is offered in the inflexible system of the big universities which do not permit the dovetailing of the studies in the completely segregated graduate schools of engineering and business administration on the one hand and the undergraduate colleges on the other hand. In order to obtain the necessary fundamentals in economics and engineering it would be necessary for a man to complete all three of these courses separately, and then he would still be without direct teaching in principles and applied methods of scientific management by an engineer with actual experience in industrial management.

PRACTICAL SUGGESTIONS FOR EXISTING SCHOOLS.

So far as existing schools of engineering are concerned, I am firmly convinced that we can prepare best for industrial management in the following manner. Separate shop-work from mechanical engineering. Employ an engineer with management experience and put him in charge of the shops. Pay him the salary necessary to secure a man of such experience. This will be higher than average prevailing professional salaries. Establish a distinct course in industrial engineering, separate from the existing engineering courses. Such a course will prepare for a field which statistics show is the actual field of employment of half the members of all the national engineering societies. Put the man who was made head of the shops at the head of this new course. Give him sufficient financial support in this department so that he can employ in his shops men of the same experience and calibre as would be eligible for foremanships in the industries. This means that salaries of from $1,500 to $2,000 per year must be paid to the instructors in these shops, irrespective of whether they have had college training or not. If less is offered we cannot secure the trade-skill and experience necessary. We must supplement these instructors by a planning department manned with instructors having had actual planning-department experience. When we remember that planning-department help is largely recruited from the ranks of foremen, we can see that here again we cannot be hampered by the traditionally low pay accorded to men who would doubtless be classified as assistants in administration if designated by the classification current in existing college organizations.

PROPOSED JOINT COMMITTEE ON THE TITLE INDUSTRIAL ENGINEER.

It is evident that we are confronted by conditions quite revolutionary so far as present standards of teaching are concerned, and we cannot meet these conditions by applying the old methods.

I have been asked for an opinion of the training, ability and experience required of a man who could legitimately style himself an efficiency engineer or an industrial engineer, to pave the way for further discussion of this question.

In reply I would state the following requirements as recommended conditions precedent to the conferring of the title of industrial engineer:

1. Eligibility to full membership in one of the national engineering societies.

2. At least three years of experience in responsible charge of some phase of industrial management work.

3. The ability to pass an examination in industrial accounts with full reference to the interlocking of manufacturing accounts with the double-entry accounting system.

I would suggest as the personnel of a committee to determine the right to use the title industrial engineer, three men from the committee of management of the American Society of Mechanical Engineers, three men from the Society for the Promotion of Engineering Education, three men from the Society for Promotion of the Science of Management and three men from the Efficiency Society of America. This committee of twelve might be allowed to waive the examination in accounting in the case of applications from men who had done such work in systematizing and other higher classes of accountancy as in their judgment made an examination unnecessary.

This committee should by resolution disapprove of the use of the title of industrial engineer or efficiency engineer by members of firms of expert book-keepers or auditors who have for advertising purposes adopted the new titles without being able to meet the requirements herein set forth.

ACADEMIC EFFICIENCY—UNDEFINED AND UNREWARDED.

BY LEONARD M. PASSANO,

Associate Professor of Mathematics, Massachusetts Institute of Technology.

Much has been written of late upon the subject of the application of the principles of scientific management to the educational institution. What has been written has been, for the most part, general and discursive; an expression of opinion merely and without the weight of authority. There has at length appeared, however, what may be considered an authoritative statement on the subject,[1] a statement which it may be well to subject to analysis in view of the importance of the questions involved.

Dr. Person, after premising that his discussion is to be "concerned with the business of academic instruction . . . ; with formal instruction of the class room and with that informal instruction which operates outside the class room," and concerned with these only, sums up the objections to the application of scientific management in education in the following paragraph.

> The product of an industrial plant is a material thing, capable of precise measurement, qualitatively as well as quantitatively; the product of an educational plant is the scholarship, culture and manliness of its graduates, attributes quantitatively and qualitatively immeasurable. The processes of an industrial plant are mechanical and subject to exact and known laws and subject to precise variation in application with reference to their effect; the processes of education are functions of the contact of minds and personalities. The material of the industrial plant is matter, capable of as precise quantitative and qualitative measurement as is its product; the material of the educational plant is the human

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[1] "Academic Efficiency," by H. S. Person, director and professor of organization and management, The Amos Tuck School, Dartmouth College. In the BULLETIN OF THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION, Vol. IV, No. 2.

mind and human nature, intangible and immeasurable, and never the same in two individuals. The principles of the organization and administration of the one cannot be therefore the same as those of the other.

The above may not be considered a fair or adequate statement of the case, but may, nevertheless, be accepted for the sake of argument and as giving no unfair advantage to the opponents of scientific management. In criticism of these objections Dr. Person says, that they consist ''simply [of] statements of opinions unsupported by data of experience or investigation, unsupported even by argument. The few that do present argument present *a priori* argument only and all essentially the same *a priori* argument,'' namely, as given above. There can be no objection to *a priori* argument if it be based upon true premises, and the assumptions underlying the above argument, says he, ''in a large way are true,'' but they ''should be subjected to investigation and experiment.''

We contend that these assumptions, these premises, are the result of investigation and long experience. To a less extent they are based upon experiment, for the experimental method is not so clearly applicable to human beings as to things; especially where the success or failure of an experiment may affect the comfort and happiness of a generation. We contend that these assumptions are based upon the experience and knowledge of past generations of educators, men not wholly ignorant of the workings of the human mind in arts, in letters and in the sciences, though ignorant perhaps of the supreme science—of management.

The science of management would have been welcomed by those men as it is welcomed by their successors. They would have accepted its laws and applied its principles, and we may do the same; asking only that its laws be shown to rest upon scientific fact, or at least upon valid scientific hypothesis, and that its principles be shown to be applicable to the field of education. The burden of proof rests upon the innovators.

But, says Professor Person, ''the *a priori* arguments against the applicability of the principles of scientific management in instruction . . . are grounded upon false premises; . . . they premise a Mark Hopkins, a log and one student, whereas our educational institutions are great aggregations instructed in groups; and that in so far as personal contact between instructor and student tends to diminish, organization must become more complex if efficiency be preserved. As organization becomes more complex the principles of scientific management become more applicable.'' Is there no *a priori* argument here, based upon false premises? The author *says*, ''our educational institutions are great aggregations instructed in groups.'' He *means* that our educational institutions are great aggregations instructed in *large groups, with little or no personal contact between teacher and student;* and it is upon the premise stated in this latter form that his argument is founded.

It has already been said that our premises are based upon long past experience. We shall presently show that the educator's ideal is not the Mark Hopkins college and shall point out that growth and complex organization do not necessarily involve loss of personal contact between student and teacher. We deny that ''as organization becomes more complex, the principles of scientific management become more applicable.'' If they are *scientific* principles they should be more readily applicable to the simple case than to the complex. Moreover, the applicability of these principles to the educational institution is the very question in dispute, and the author quietly injects here his thesis as a valid premise for his argument. Finally, he tacitly assumes the superiority of "scientific management'' to any other form of management of the complex educational organization. Having exposed thus his insecure foundation, let us proceed to test the stability of the edifice erected thereon.

The scientific manager concedes that there is one system not inferior to his own. ''I know,'' he says, ''of no more efficient educational organization . . . as to personnel, equipment or method,'' than the ideal Mark Hopkins college. But to many educators it seems that this ideal may be, and in some instances has been, improved upon. Mark Hopkins—we must have the gifted individual—with a class of fifteen students would seem to be a more perfect combination still. The contact, the friction, the interplay of the minds of such a group of teacher and students is more stimulating and helpful both to learner and teacher than is even the harmony of that famed duet.

The combination of a gifted and sincere teacher with a small number of earnest and industrious students would seem to be the highest ideal of the educational institution. It is an ideal perhaps not easily or often realized, for "the supply of Mark Hopkins is limited," and our colleges have grown to such numbers as "one, two, three, four and even five thousand students"; so that "personal contact between instructor and student diminishes . . . to almost nothing, and . . . efficiency in organization must make up for diminished personal contact."

Waiving the question whether efficiency in organization *can* make up for diminished personal contact, we may deny that it *must.* The obvious and best remedy for the evil would be to increase the supply of Mark Hopkins to meet the demand of a college with an enrollment of even five thousand. Possibly, too, it may be found that a college of five thousand students is neither necessary nor desirable. Such numbers may be due to accretion and not to growth. The remedy may lie partly in the discontinuance of the covert advertising of the rival educational factories, and partly in a reversion to older and saner ideas as to the college and the college student; to the idea of the college as a seat of learning, and to the idea of the student as an earnest seeker after knowledge. The college might then be both smaller and better.

If, however, the large college be a normal growth, it may reasonably be assumed that the growth in numbers of gifted teachers is commensurate. They may not now be teaching, but if the demand is made the supply will be forthcoming; that is, if the rewards are made, not alluring indeed, but merely ample. Not every man possessed of a high order of teaching ability is willing to become a follower of St. Francis.

Is not this the true crux of the matter; namely, the cost? And is not scientific management applied to education an effort rather to provide a moderately good education at a low cost, than to provide the best education at whatever cost may be necessary? Certainly, and justly, scientific management, as applied to commercial enterprises, has for its chief aim the earning of greater profits by a reduction of the costs, and it is reasonable to believe that it carries its aims, as it carries its principles, into the field of education.

Even if the cost of increasing the supply of Mark Hopkins be prohibitive, does it necessarily follow, as is asserted, that organization is preferable to the small personal contact in large classes? To many it seems that the inspirational value of lectures to large classes is underestimated. Phillips Brooks, preaching ideals of duty; Agassiz lecturing on zoölogy; George William Curtis, pleading for civil service reform; Poincaré, describing the evolution of stellar systems, might inspire audiences of even a thousand undergraduates. And lesser men to smaller numbers do, in their lectures, give to their audience an inspiring knowledge of literature, history and science. Many of their listeners doubtless go away uninstructed and unrefreshed. Such would depart famished from the springs of Helicon and uninspired from the voice on Sinai.

With these, what shall be done? The answer of scientific management applied to education is, refer them to "functionalized advisors, picked men" who spend their days in giving advice to five thousand students, and who do nothing but advise; who "save much wasted energy of students by relieving them of the necessity of deciding the *how* in situations which they have not the experience to decide safely." Then if the advice is scorned or neglected the student is turned over to the "functional disciplinarian" whose painful and perpetual duty is obvious.

Granting the desirability of "functionalized" advice and discipline, where are the administrators of such duties to be found? Is the giving of advice to a thousand, even to a hundred young men, on every question that may arise as to their duty, their work or their profession, so simple a matter that men to fill such offices can be easily found? In an individual case where will the "functionalized advisor" get the information on which to base his advice? He will get his "scientific" data from the previous records of the student, from information which the student volunteers or which is elicited by cross examination, and from information furnished by the young man's teachers. This is all second-hand information, data secured by consulting authorities and not by original research. The original investigator of the student, he who knows the youth most intimately, is his teacher, and to him the other sources of information are equally open. Unless the professional advisors are men of far greater breadth of outlook, worldly wisdom, and insight into the human character than are the teachers in our colleges, the latter would seem to be much better fitted to advise the student in his perplexities. But if the advisors are men of such transcendent ability they must, we warn the scientific manager, be paid for.

There are indications, however, that under scientific management advice and discipline, as well as teaching, are to be "standardized," with a consequent enormous gain in simplicity. Student A consults Advisor B who fills out a blank form stating A's age, height, weight, his brachycephicality or dolichocephicality, his reaction time, his coefficient of intelligence—previously determined by the functionalized psychometrist—all the scientific data of his case, which need not be enumerated. Then Advisor B, after consulting his catalogue index and shuffling the cards, hands to student A advice DnKy, to be followed, if the advice prove inefficacious, by discipline ROd4. Truly, as we have remarked, an enormous gain in simplicity!

Indeed, why should not the principles of scientific management be carried to the logical extreme in education? With "functional teaching . . . functional administration (discipline), functional advising and functional supervision and guidance of non-classroom educative influences," why should not youth engage in functionalized study, receive a functionalized degree, and thence, with a functionalized education, pass onward to the functionalized battle of life?

With this compare the chaotic state of actual education in which "the obligations of the instructor embrace practically all institutional functions except general administration," for which last even, to the wonder of the scientific manager, there seems to have arisen a demand on the part of the teaching force. The instructing staff seems to wish to increase rather than decrease the number of its functional activities.

However that may be the teacher undoubtedly has many and divers functions to perform; too many, say the advocates of scientific management; so many that "none is performed efficiently, not even instruction itself as efficiently as it might be."

To the last statement no exception can be taken. No human task is performed "as efficiently as it might be." But that none of the functions of the teacher is efficiently performed is a dogmatic statement of the kind which the maker of the statement deprecates, of the kind which he attributes to the opponents of scientific management in education: "statements of opinions unsupported by data of experience or investigation, unsupported even by argument," unless indeed the question is begged by the use of the words "efficiently performed." If "efficiently" means according to the principles of scientific management and with the aims of that system in view, the statement is correct. If efficiently means—but what is the meaning of efficiency? Those who would apply the principles of scientific management to education nowhere define the word, nowhere tell how efficiency can be measured. A "scientific" system based upon "scientific" data is to be applied to educational reform without explanation or definition of the most fundamental datum of that system. Oh, *varium et mutabile semper—scientia!*

Granting that the work of the teacher is not being done as well as it might be, or should be, is the reason therefor that he has too varied duties to perform? The trouble would seem to be not the diversity of functions but rather too onerous duties; not too *many* functions but too *much*. The advocates of scientific management in education say that it is these administrative "duties which shut the instructors off from personal contact with students; which makes [*sic*] the contact they seem to have unreal and gives them a false view of students."

No proof of this statement is offered. It is simply the opinion of the author quoted, who advances this opinion as an argument for the introduction of scientific management in the college. He further says: "An instructor who does *nothing but teach*,[1] but has *leisure* for informal intercourse with students, can learn to know the student as he really is, and by the power that knowledge gives him can 'reach' the student and inspire him in the classroom."

Let us analyze this statement. Is it because an instructor "does nothing but teach" that he is enabled "to know the student as he really is," or is it because he "has leisure for informal intercourse with students" that he is able to understand, to "reach" and to inspire them? The argument is in fact as follows: The teacher should have leisure. He should use this leisure for informal intercourse with students. Informal intercourse with students gives knowledge of what the student really is. Knowledge of what the student really is furnishes power to reach and inspire the student.

Whether the instructor "does nothing but teach" has no bearing upon the case. He may do nothing but teach and be teaching so continuously that he has no opportunity for informal intercourse. He may do nothing but teach and become so narrowly specialized, so limited in outlook, so atrophied in character as to be helpless to the student and hopeless for himself. Not functionalization but diversity and leisure is the great need in education; not delimitation of the teacher's powers but opportunity to employ them. But again the crux obtrudes itself: the *cost* of leisure and opportunity.

Another dictum of the advocate of scientific management in education is that "it is a principle of scientific management that the determination of *how* be entrusted to specialists and not left to the workman, thereby eliminating the waste of misapplied effort.''

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[1] The italics are the present writer's.

Two things he has forgotten. First: he is trying to prove the applicability of the principles of scientific management to educational institutions.

His argument is as follows:

Theorem: to prove that the principles of scientific management are applicable to, and should be applied to the educational institution.

Proof: The principles of scientific management have proved efficacious in many industrial institutions. It is *my opinion* that if these principles were applied to the educational institution certain beneficial results would follow. These results are desired and striven for by educators. Therefore, the principles of scientific management are applicable to, and should be applied to the educational institution. Q. E. D.!

Second: The counsel for—one feels tempted to say the *offence*—has forgotten that in teaching, as in many other professions and trades, the workman is the specialist to whom must be left ''the determination of how.''

Would the scientific manager, it may be asked, select a group of art critics, specialists, to determine the ''how'' for painters and sculptors? Yet the canvas and pigments, the clay and the stone are infinitely simple things as compared with the human mind with which the educator deals. Functional organization, doubtless, would produce pictures of a kind; and functional organization, doubtless, would produce education—of a kind.

But the end is not yet. ''To apply one principle [of scientific management] makes necessary application of all the others [we shall return to this later], for the body of principles of scientific management is an organic whole; . . . . Functional organization involves wise selection of men (instructors, advisors, disciplinarians, etc.), wise selection of equipment (pedagogical methods and apparatus) [with the implication that unfunctional organization does not involve such wise selection, or is incapable of it], and wise classification of *material* (*students;* according to scholarship, natural ability, preparation, health, temperament, etc.). [The present writer's italicization of words which will be especially considered later.] It requires these wise selections and, what is more significant, *it, and it alone, makes these selections possible.*"[1]

We may pause a moment to observe that modesty does not appear to be one of the principles of scientific management.

If we consider the criticisms of this paragraph in the inverse order of their enumeration above, we may seek first "the determination of how" functional organization and it alone has the power of making wise selections of men and things. We are not told. The human body is a highly functionalized organization and its functional members, selected through millions of years of evolution, depend for wise selection of their activities upon the brain, the mind, the soul, if you will. What is the selective evolution in scientific management? What is its selective mind, what is its soul? Scientific management is a "business proposition," and its soul is greater gain and less cost; a perfectly legitimate spirit in business enterprise, but a spirit whose rule in educational affairs is to be deplored and combatted.

In the next place, the author quoted speaks of students as "material," raw material, to be classified. The present writer refuses to accept this definition of the raw material of the educational factory, and in another place he has endeavored to show that the student is really a workman. But calling the student raw material for the sake of argument, let us follow the scientific manager farther. He says: "An immediate, tangible, practical reward for efficiency is unquestionably a powerful force. Is it not possible that something more could be made of this principle by educators? The reward of being permitted to play on a foot-ball team, provided he is not below a certain rank in scholarship, has inspired many an athlete to better scholarship than he would otherwise have shown."

What a galaxy of glittering rewards is opened up by this

[1] The present writer's italics.

sentence! It used to be thought that education, like virtue, was its own reward, and that knowledge, wisdom and learning should be diligently pursued for their own sake. Under scientific management they are to be pursued for the sake of athletic honors. If we might paraphrase some once famous verses we should say,

> One French verb for the relay team;
> Two Latin verbs for the base-ball team;
> The whole Greek grammar for the foot-ball team.
> So study, boys, study with care,
> In the presence of the functional managaire.

But let us return to prose and earth, and ask by what principle of scientific management "rewards" are offered to the "raw material" of a factory as bonus for "efficiency" of that raw material! To the historic inquiry "what is truth?" we may in bewilderment add the inquiry, what is science? And may say, if this be science give us—common sense.

Finally, the scientific manager of the educational institution has said that it is necessary to apply *all* of the principles of scientific management, but nowhere, except in the case of the raw material mentioned above, does he make a suggestion of a bonus to the workman, the teacher, for efficiency. Possibly, knowing the kind of workman with whom he is dealing, he is assured that none would ever reach an efficiency—undefined, it will be remembered—an efficiency high enough to earn a bonus; or perhaps the workman's reward is indicated in the following paragraph: "The teacher who is relieved of the burden of too many functions would find himself freer to investigate widely, think deeply, know life and form individual judgments. . . . The erect figure, the keen eye, the intense earnestness, the precise statement of fact and principle, the wise choice of interesting and illuminating illustrations, characteristics which, in addition to scholarship, make the great teacher, would continue to exist and to arouse and inspire." We may well end here. lest by further functionalized management there be taken from the teacher "even that which he hath."

Discussion.

Professor J. P. J. Williams (by letter): I wish to express my keen appreciation of the paper by Professor Passano on "Academic Efficiency." Probably few of those who attended the Boston meeting of this Society, when the exponents of the new schools of efficiency tried to show us how to apply the principles of scientific management to teaching, obtained more than a hazy conception of the subject.

Nevertheless, I believe that there are certain principles of efficiency which do have definite practical working value, and are too generally neglected or ignored in our engineering education. My experience of nine years teaching engineering in five educational institutions, has led to the firm conviction that our educational processes could be greatly improved by the general adoption of certain common sense methods based upon definite principles of efficiency. The efficiency movement does have its value in the emphasis it places upon the necessity for daily, continuous applications of fundamental principles. In order to lead up to such definite application. I would emphasize two essential characteristics of an ideal engineering education; first, the severe and effective training of the student to do things efficiently, to develop his power of accomplishment through self-expression, and to acquire ability to earn a respectable living for himself and a possible future family, and second, the vision of the joy of service, and a realization of the supreme value of socially constructive effort accompanied by unselfish devotion to the profession and to the community as a whole.

Unfortunately the practicable application of these two ideals tends to be mutually exclusive. A completely absorbing desire to develop individual student ability in accomplishing results of a practical nature tends to overcrowd the curriculum with too many courses, each cumbered with detail. On the other hand, the broadening and socializing of our engineering education too often results in poorly trained or even slipshod, lazy graduates who are a disgrace to any institution. The problem can best be solved by the adoption of a mean between the two possible extremes. In fact there is no real conflict between the two conceptions. Severe, practical training can be accompanied and illuminated by broad conceptions of life and work. In fact, theories can be most effectively and convincingly illuminated, demonstrated or proved by applications to simple every-day practical problems such as the engineer meets in many forms. Our educational activity should, therefore, be related as closely as possible to life and life problems in order to be really efficient.

What practical methods will result in the training of students in ability to accomplish results? Surely not those that are produced by the attitude that they are the raw material upon which the teacher works, but rather those based upon the conception that the teacher is a co-worker with the student, an older brother who inspires to earnest, enthusiastic endeavor. Is it not the teacher's function to clothe with flesh and blood, and breathe the spirit of life into the dry bones of text-books and cut-and-dried routine? Can he not thus create living records which increase and multiply his power until it is of infinitely greater value than all the books, or all the material engineering designs that he could possibly create?

This conception of the true teaching function should be kept clearly in mind in attempting to apply several elementary working principles of efficiency which cannot be ignored. First in importance in training engineers to accomplish results is the insistence upon rapid, accurate and complete solutions of definite practical problems. Those most persistent enemies of the student, bad habits of work and wrong attitude toward work, combined with waste of time due to physical and mental inertia, must be overcome by the wonderful power of a compelling interest and concentration on a definite purpose. Every student should not only be told how to study and work effectively, but actually forced by the requirements of the course to change bad habits and learn to know the "glory of action." Definite practical set tasks of the kind met with in actual life will not only appeal to the interest and constructive desires of the student, but also tend to avoid that most pernicious time-serving and bell, or clock-obeying habit of mind which our method of allotting regular hours to various courses tends to develop.

Is it not true that we are violating a fundamental requirement of effective work by making impossible any long-continued concentration of mind and effort on any one subject by our many single-hour lectures or class periods? This is, of course, a problem in applied psychology, and I believe there are many other just such problems that we should ask the psychologist to help us to solve. It seems quite probable that in many courses there is an appalling waste of time caused by this continual shifting of classes and subjects and teachers. And there is a further loss due to the absence of any proper coördination and correlation among different courses. Every individual course should have its definite, well-understood place and meaning in the ideal course as a whole, and the introductory lecture should always make clear just what this larger meaning of the course really is and show the relations of the parts to the whole.

Certain practical methods can be suggested to increase the effectiveness of the teacher's work with his students. The less the time required by the teacher to explain and talk, the greater is his efficiency. The more general and animated the discussion by the students, the greater is their gain in understanding. To prevent the development of parasites, each student should be required to work and think independently, and the habit of self-reliance and courage should be developed by not allowing the students to appeal to "teacher" to carry them over all difficulties. Definite daily tasks emphasizing the value of time, thoroughness and accuracy, and testing the individual development of thought power should be assigned and their accomplishment absolutely required. To be sure, there is a great gulf between the ideal and the actual, and it takes time and infinite patience to obtain results, yet this is no reason for becoming easygoing and submitting to the tremendous pressure of student mediocrity, and lowering standards. If every student could only adopt for his motto the following words of the Veda, the teacher's troubles would tend to vanish:

> "Look well unto this day;
> "For in its brief course lie all the verities and realities of your existence;
> "The bliss of growth, the splendor of beauty, the glory of action;
> "For yesterday is but a dream, and to-morrow is only a vision,
> "But to-day, well lived, will make every yesterday a dream of happiness,
> and every to-morrow a vision of hope.
> "Look well, therefore, unto this day."

Just one word only is necessary in adding to the second conception of the ideal engineering education, *i. e.*, the idea of education for service. Mr. Rayner in his BULLETIN paper on "Socializing our Engineering Education" has expressed completely the thought which I have in mind. No training can be made more completely effective in producing energetic men who do their work confidently, hopefully and successfully, than the right kind of broad engineering training. But such training cannot result from highly-specialized, overcrowded curricula such as are found in many institutions. Practice in public speaking and debate; courses in economics and sociology; thorough training in the use of technical English; presentation of abstracts of current engineering literature or, better still, original papers on live engineering topics; attendance at meetings addressed by practicing engineers and alumni; reports on visits to engineering works of all kinds; and above all, a vital and growing realization of the broad, creative character of engineering work, are all essentials of this right kind of engineering education.

In connection with the discussion of the proportion of his time which a teacher should devote to teaching I would say that my varied experience has convinced me that there is great danger when a teacher devotes more than a very small amount of time to outside consulting practice during regular university sessions. No man can serve two masters, and the educational work is sure to suffer neglect and lose vitality and effectiveness because the inevitable tendency of consulting practice is toward absorbing devotion to interesting practical work and profit.

Activity of a helpful and productive character is the chief mark of a live and progressive society, and I should like to see adopted by the S. P. E. E. some such committee organization as that of the American Society for Testing Materials. Our membership in this Society would mean much more if each member was appointed on some regular committee, working on a definite real problem in education. For example, one such committee should consider fully this question of academic efficiency and perhaps attempt to formulate an ideal engineering course, brought up to date and based upon all available papers and discussions on the subject.

The second definite suggestion is that the Society adopt plans for establishing local branches at various institutions wherever feasible. Regular meetings should be held for active discussion to keep alive the interest and enthusiasm developed at the annual meetings. The three large American societies of engineers are all adopting this plan successfully, and there seems to me to be no reason, unless it is apathy, to prevent similar action by the S. P. E. E.

PRACTICAL MATHEMATICS.

BY W. S. FRANKLIN,

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In the teaching of mathematics every effort should be made to appeal to sense material and to the quantitative notions which permeate everyday life; and mathematical principles and relations should be visualized wherever it is possible. The development of workable ideas in a young man's mind is the most important object of science teaching; and ideas, like everything else in this world, have to be made out of *something.* Many teachers, however, seem to think that ideas can be built up in a young man's mind by a sort of hocus pocus out of nothing; but the only way to marshall the mind-stuff of a young man for the manufacture of ideas is to introduce the drag net of physical suggestion into every discussion. There is no other way to bring intuitive and sense material into the field of consciousness where it may be organized into a structure of ideas. An abstract and conventional treatment tends always to inhibit the influx of elemental mind-stuff into the field of consciousness, and such a treatment results at best in the building up (in the mind) of a theoretical structure which can have no mental traffic with anything outside of its own narrow boundaries. Such a state of mind, even when it is actually produced, is nothing but a kind of idiocy; and to call it a knowledge of mathematics is the silliest kind of scholasticism.

Many teachers of mathematics do, no doubt, appeal to sense material, and what we say as to the urgent importance of such appeal is likely to be lost on them; for we have in mind a degree of appeal which is greater, perhaps than has ever been attempted, and *especially we urge the importance of incorporating this appeal in the printed text.* Men have but little native ability to understand impersonal and non-anthropomorphic writing, and nothing in elementary science training is more important than to develop this kind of ability. It depends not only upon *the possession of ideas* BUT IT DEMANDS THE ACQUIREMENT OF SOME OF THESE IDEAS BY READING.

According to our experience, engineering students willingly spend almost any amount of time and effort in algebraic transformations, in memorizing formulae and in solving numerical problems, but they cannot be made to read with care the briefest written statement or argument however simple it may be and however clearly written. and when they do read they cannot understand. This obstinate unwillingness to read and this fixed inability to understand are due very largely, we believe. to the influence of our mathematics teaching. What else could be expected when the great majority of engineering students never get a single idea from the book they study hardest—and hate the worst, their text book on calculus?

Professor Sylvester once said that during his undergraduate days his liking for calculus led his mates to look upon him with a kind of awe as a man who like Dante had seen Hell. But to study calculus without understanding is Hell; and the man to be likened to Dante is he who sees young men study, knowing that they do not understand! But let us turn from generalities to particulars.

Several years ago we gave the following "original" problem to a group of Freshmen engineering students as part of a final examination in elementary mechanics.

"A cart moves due northwards at a velocity of 11 feet per second. A man pushes downwards on the cart with a force of 200 pounds and a mule pulls northwards on the cart with a force of 50 pounds. At what rate does the man do work and at what rate does the mule do work?"

Forty-four per cent. of the class found that the man was developing four horse-power and the mule one horse-power! These students were not exactly stupid, either, they were merely Wild Indians of a very familiar and ubiquitous kind; their physical imagination had never been stretched beyond games and guns, or, maybe, never beyond articles of food and the members of their bodies! It is certain, at any rate, that to have specified the part of his body used by the man in the problem in pushing against the cart would have brought the problem vividly before every member of the class in its real aspects! Or, perhaps, many of the class were obsessed with the idea that any study in college must necessarily refer to elegant and unfamiliar things, like the boy who was asked to explain what is meant by the heat of combustion of coal. This boy answered at once, "It is the amount of heat obtained from a pound of coal," but he could not be led to say "When the coal is burned." And when the instructor finally put the direct question, "How do you get heat out of coal?" the boy answered, stammering, "Why, professor, I ——— I don't know."

This identical boy, who seemed not to know that coal must be burned to get heat out of it, came upon the following statement on the 23rd page of his Calculus in a two-page discussion of discontinuous functions and he came upon it several months before the question as to the heat of combustion was put to him:

" Another discontinuity is seen in the function

$$y = \frac{2^{1/x} + 2}{2^{1/x} + 1}$$

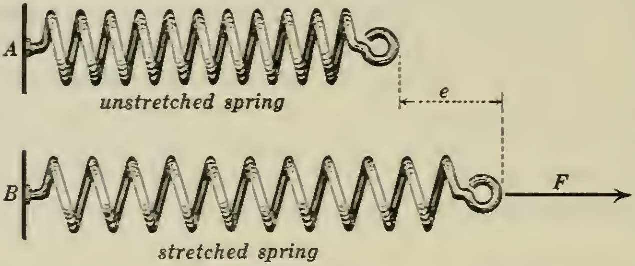
when $x = 0$. Here y approaches two limits, according as x approaches zero through positive or negative values.

$$\text{Lim}_{x=+0} \frac{2^{1/x} + 2}{2^{1/x} + 1} = 1, \quad \text{Lim}_{x=-0} \frac{2^{1/x} + 2}{2^{1/x} + 1} = 2.$$

We see that when $x = 0$ the curve jumps from $y = 2$ to $y = 1$, that is from B to A (referring to a figure)."

In all probability, after "seeing" y jump in this elegant and unfamiliar way, the boy really did not remember that coal must be burned to get heat out of it! Please recall Sylvester's allusion to Dante and consider what Dante saw (and understood, be it said to his everlasting fame), souls who had abandoned hope—and their tormentors!

Let us take another example. We recently gave to a group of Junior engineering students two problems involving the use of calculus, and there exists no problem involving the use of calculus which is simpler than either of the two we gave. The simpler of the two problems was as follows (the sketch here shown was given also to make the problem perfectly clear):



"The stretching force F, as shown in the sketch, is equal to ke where k is a constant. Find the expression for the amount of work done in stretching the spring from condition A to condition B."

There were 33 students in the class who had passed all of their freshman and sophomore mathematics, including analytical geometry, differential calculus, integral calculus, differential equations and analytical mechanics. Only 4 men formulated the problem correctly and derived the correct result: and of the 29 who failed utterly with a grade of zero 13 tried to argue the problem without using calculus! And yet, in the institution where this degree of mathematical power is realized, from 40 to 60 per cent. of the men fail to pass in each of the four successive terms of mathematics!

We realize with perfect clearness that these examples may be taken as a basis for unfavorable criticism of physics teaching, *if we assume that power in mathematics has only to do with quick and complete response to a question like this. "Integrate kay Eee dee Eee between the limits Eee equals zero and Eee equals kay Eee!"* These examples show how nearly impossible it is to accomplish anything in elementary science teaching in the face of present-day mathematics instruction.

What is needed is to divorce the beginnings of elementary calculus from formal algebra, and to teach it as a branch of old-fashioned mental arithmetic. The widespread tendency towards the premature introduction of mathematical refinements and elaborations and the almost complete suppression of ideas by symbolism is perhaps the most serious fault in mathematics teaching. "Natural philosophy," says Bacon, "is not yet to be found unadulterated but is impure and corrupted by mathematics which ought rather to terminate natural philosophy than to generate or create it."

We have tried to keep away from vague generalities in the preparation of this brief, and yet in looking it over we realize that many of our statements grow out of very general considerations. It could not, perhaps, be otherwise, but our point of view seems to be different from that of most of our fellow-teachers, and therefore not to be easily understood by them. We assume, however, that most teachers recognize sorely the need of what Bacon listed as a deficiency in his day, namely, "The Traditive Lamp or the Proper Method of Delivering Down the Sciences to Posterity." We also assume that some teachers of elementary mathematical science are not wholly pleased with what they do. But especially, recognizing the very great preponderance of what may be variously called *ideas*, or *method*, or *theory*, in what is teachable in science, and knowing what a vast difference there is between such things as held in a system of philosophy and as realized in life, we recall this humiliating passage from Goethe:

> "Grau, theurer Freund, ist alle Theorie
> Und grün des Lebens goldener Baum."

THE MAXWELLIAN METHOD.

The method of the purist in mathematics is to develop an entirely consistent and rigorous system of symbolic logic, independently of every element of perception and judgment; and another method in mathematics is represented by Maxwell's great treatise on "Electricity and Magnetism," where highly elaborate mathematical forms spring, full fledged and rich, from physical ideas, bringing mathematics at once into touch with the experimental sciences and leaving the pure algebraist with his labored logic hopelessly behind.

The difference between these two methods is not the difference between rigor and mere plausibility, it is mainly the difference between a proud contempt for intuition on the one hand, and a straightforward use of intuition on the other hand. Consider, for example, the usual treatment of the discontinuity of functions in elementary treatises on calculus. What must any concretely-minded young man think of a writer who defines discontinuity as a break in a curve but who turns away from this definition as being intuitive, and proceeds to an algebraic discussion! Every concretely-minded young man would recognize the propriety of turning away from the broken curve in this matter; but to turn to algebra rather than to the vision of a poor trapped sparrow butting his head against a window pane, argues a kind of deep set and hopeless insanity!

In our opinion even elementary mathematics, including calculus, can be developed in full by the Maxwellian method on the basis of physical ideas, *and as logically as by the classical method.* But of course there is a difference in the logic. In one case the logic is machine made and its substance is algebraic transformation by rule; whereas, in the other case, the logic is involved in the perception of relationships between fairly complicated but entirely precise and unimpeachable ideas.

The association of a physical quantity with a definite physical thing or condition always involves a sharply defined idea of invariance, as does also every mathematical definition in elementary physics and chemistry. Indeed the invariant relations which intervene between raw unformulated nature and what is ordinarily called mathematics are very great in number, and many of them rest upon very complicated experimental operations; and their clear recognition places an extremely severe demand upon the mind of any young man.* The necessity of rigorous thinking is much greater and more exacting in this border region than it is in the region of pure mathematics. Unfortunately, however, our conventional courses in mathematics seem always to produce a hopeless habit of vagueness in regard to mathematical ideas. For example, when asked to state Joule's Law, a student will say *aitch equals arr aye square tee!* It is difficult to get a student to say that *the amount of heat generated in a particular piece of wire during a given time is proportional to the square of the current in the wire and to the time that the current continues to flow.* It is difficult to get a student to appreciate the necessity of particularization in such a statement; by writing his statement down phonetically, he can indeed be shamed out of the statement of a physical law by the mere pronunciation of letters, but he is apt to think his statement completely and definitely physical when he says "Heat is proportional to current squared multiplied by time." It is extremely difficult to get a student to appreciate the invariant relation between the proportionality factor and the particular piece of wire, and it is hardest of all to bring a student to the point where his mind is directed to the physical operation which defines a quantity of heat, or a strength of current when such a quantity is mentioned.

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* Consider a movement of the x, y and z axes of refernce. This movement is a physical operation, and it is represented in algebraic terms as a linear transformation; that is to say, the coördinates of a point with respect to the new axes are linear functions of the coördinates of the same point with respect to the old axes. There are certain functions of x, y and z which are not changed by this linear transformation, and these functions are called invariants with respect to this particular transformation. That is to say, the movement of the axes of reference (a physical operation) leaves certain invariant relations outstanding. The systematic physical operations which are involved in any more or less elaborate experimental research or test always leave certain invariant relations outstanding, the clear and precise recognition of which is the essential part of the logic of experimental physical science—and a real and important branch of mathematics. Indeed the border region above mentioned is permeated by a most exacting kind of mathematics, which is akin to the group theory and to the theory of invariants.

Mathematics as it is given to students in our conventional courses is entirely lacking in that quality of precision and definiteness which goes with complete particularization. This statement will seem to be an exaggeration to many teachers, but let them consider that we mean by complete particularization that which would satisfy the most childish person in a talk about apples! The precision and definiteness, which goes with complete particularization is perhaps the only kind of precision and definiteness a beginner can appreciate, and we believe it is a great mistake to suppose that in the study of abstract mathematics a peculiar and inevitable kind of precision and rigor constrains the mind of a young man as a mould constrains molten iron! One might as well try to shape an iron casting in a mould of pure mist as to attempt to form a young man's mind by conventional mathematics.

The Study of Mathematical Science.

The greatest difficulty in the teaching of the mathematical sciences in the college and technical school comes from the fact that the average young man does not instinctively appreciate the necessity of rigorous thinking, and the greatest error on the part of a serious teacher is to assume that this difficulty can be met by mere exactions.*

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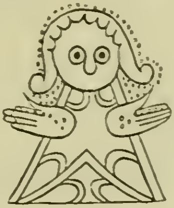
* This is a natural difficulty, and it must be squarely met. A second difficulty is that young men in their study of the mathematical sciences are lacking in that eager interest which is called scientific curiosity. We are convinced, however, that this lack of interest is not inherent in the average young man; it grows out of the entire absence of suggestiveness in his mathematical studies and the inhibition of sense by the excessive formalities of ordinary mathematics instruction.

Nothing, perhaps, is farther from the usual ideals of mathematics than painting and sculpture: not indeed that the artist is free from exactions, for the saying that art is long and life is short certainly antedates our widespread academic pride in the difficulties of mathematics; but because the forms of expression in art are so different from the forms of expression in the mathematical sciences. And yet nothing has ever been said which can be more justly applied in criticism of our conventional courses in mathematics than the following criticism of conventionalized art. This criticism was made by one who, as Mazzini said, could hold a fact more fixedly in mind than any other man living in his time and set it forth more clearly. The criticism is expressed in terms of a contrast between The Two Paths* of art and it is illustrated by examples chosen from early barbarisms.

"The substitution of conventionalism for sympathy with observed life is the first characteristic of the hopeless work of all ages, and it is eminently manifested in the accompanying picture of an angel from a psalter of the Eighth Century which is to be found in the library of St. John's College, Cambridge. This angel is a barbarism from which nothing could emerge, for which no future was possible but extinction. It represents an utterly dead school of art which closed its eyes to natural facts (for however ignorant a person may be he need only look at a human being to see that it has a mouth as well as eyes) and made the attempt to adorn or idealize



An angel of the eighth century. The beginnings of art in England.

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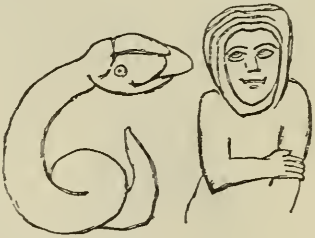
* The title of Ruskin's lecture from which the criticism is taken.

natural facts according to its own notions (for it put red spots in the middle of the shands and sharpened the thumbs thinking to improve them). Here you have an example of the worst that is possible in idealism. Whenever people don't look at nature they always think they can improve her.''

''From this dead barbarism let us turn to a living barbarism, to work done by hands as rude and by minds as uninformed, let us turn to a picture of the Serpent Beguiling Eve, from the Church of St. Ambrogio of Milan. Its date is not known but it is barbarous enough for any date: but rude and ludicrous as the sketch is, it does certainly have the elements of life in it. The workman's whole aim was straight at the facts, and not merely at the facts but at the very heart of the facts, for he did indeed show Eve's state of mind, that she is pleased at being flattered and yet in an uncomfortable mood of hesitation; some look of listening, of complacency and embarrassment he did verily get into the picture; note the eyes slightly askance, the lips compressed and the right hand nervously grasping the left arm. Nothing was impossible to the people who began their art thus. The world was open to them and all that is in it; whereas nothing was possible to the man who did the symmetrical angel, the world was keyless to him. He built a cell for himself in which he was barred up forever.''



The Serpent Beguiling Eve. The beginnings of art in Italy.

Our conventionalized courses in mathematics do not, however, take strong enough hold on young men to shut them up, as in a cell, forever! No, they certainly do not! But these courses do tend to separate ordinary mathematical ideas from sense material: whereas the very essence of physics and chemistry is to bring mathematical ideas to bear upon sense material!

Our demand is that calculus, for example, be made intelligible to students; and in making this demand we do not make any objection whatever to the placing of exactions upon young men. In fact we know that very great exactions are necessary. But to place before young men that which is exacting and unintelligible is a fatal error, an error which seems to be widely prevalent among mathematics teachers.

The Use of Differentials in Calculus.

We find it difficult to understand the rabid objection of some of our mathematical friends to the old fashioned way of talking about differentials, except on the assumption that the idea of a limit must be much more difficult to the student of mathematics, in a narrow sense, than to the student of physics. Nothing indeed so clearly indicates the extreme difficulty which one has had in the acquirement of a precise idea as the notion that everyone else must be in a state of confusion in regard thereto, and our mathematical friends seem to imagine that they are combating a widespread confusion of mind in this matter, whereas the question at issue is merely as to the relative merits of two modes of expression.

Consider the simple function $y = ax^2$ from which we find

$$\frac{\Delta y}{\Delta x} = 2ax + a \cdot \Delta x,$$

and from this expression it is evident that $\Delta y / \Delta x$ approaches $2ax$ as its limiting value as Δx approaches zero. That is, we have:

$$\frac{dx}{dy} = 2ax.$$

The use of the complicated group of letters dy/dx for the derivative reminds one of the ratio $\Delta y/\Delta x$, the use of d instead of Δ is intended to bring to mind the limiting value of $\Delta y/\Delta x$, *and the great majority of writers on applied mathematics are in the habit of speaking of the differential, dx, as a vanishing increment of x in order that the above argument may thereby be called to mind.* The sole value of this mode of expression is its suggestiveness.

THE SYLLABUS DEFINITION OF A DIFFERENTIAL.

After a body falls for one second under the action of gravity it has a velocity of 32 feet per second, *which means that the body would travel 32 feet during the next second if its velocity were to remain unchanged.* Similarly, in the simple differential expression $dy = 2ax \cdot dx$, the variable y changes 20 times as fast as x when x has reached the value of 10, *which means that dy (the actual finite change of y) would be 20 times dx (the actual finite change of x) if y were to continue to change 20 times as fast as x.* This statement involves a precise definition of dy and dx, there is no doubt about that; but what use can such a definition be for the purpose of simple, concrete and suggestive discussion with its extremely awkward "would be's" and "if's"? And yet this is the meaning which the purists wish to have always brought to mind when the differentials dy and dx are mentioned! In order to bring out the real question at issue let us compare the following three statements, A, B and C.

A. Example of an Argument for Setting up a Differential Equation.—Let it be required to set up an expression for the derivative dK/dr, where K is the moment of inertia of a circular disk of radius r referred to its axis of figure. Let m be the mass per unit area of the disk. Then $[\pi(r+\Delta r)^2 - \pi r^2]m$ or $2\pi rm \cdot \Delta r + \pi m(\Delta r)^2$ is the added mass due to the increment Δr. The distance of the added mass from the axis is greater than r and less than $r + \Delta r$; therefore* the increment of K lies between

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* The reason for multiplying the added mass by the square of its distance from the axis is here omitted.

$r^2[2\pi rm\cdot\Delta r+\pi m(\Delta r)^2]$ and $(r+\Delta r)^2[2\pi mr\cdot\Delta r+\pi m(\Delta r)^2]$.

Therefore, expanding and collecting terms, we get:

$$\frac{\Delta K}{\Delta r} \text{ lies between } \{2\pi r^3m+\pi r^2m\cdot\Delta r\}$$

and

$$\{2\pi r^3m+5\pi r^2m\cdot\Delta r+4\pi rm(\Delta r)^2+\pi m(\Delta r)^3\},$$

but both of these expressions approach $2\pi r^3m$ as a limit as Δr approaches zero, and therefore the limiting value of $\Delta K/\Delta r$ is $2\pi r^3m$. That is:

$$\frac{dK}{dr}=2\pi mr^3.$$

B. An Epitome of the Argument A.—The added mass is $2\pi rm\cdot dr$ (because one recognizes $2\pi r\cdot dr$ as the limiting form for expressing the area of a narrow circular annulus).

We multiply the added mass by r^2 to get dK (because one recognizes r^2 as the limiting value of anything which lies between r^2 and $(r+\Delta r)^2$).

Therefore $dK=2\pi r^3m\cdot dr$.

Note.—Every one no doubt appreciates the fallacies in this kind of abbreviated argument, but the mathematicians alone seem not to appreciate its value as a suggestive outline. The matter in the parentheses is indeed usually omitted from abbreviated arguments of this kind, but even when such material is included the argument is incomplete because it does not include explicitly everything that is given under *A*. The great majority of writers on applied mathematics do not use the Δ notation in the early part of an argument and change to the d notation when the limit is determined, but for brevity they use the d notation first and last.

C. Attempt to Give an Epitome of the Argument A Using the Syllabus Definition of the Differential.—The differential dK is the increase which would be produced in K due to a finite increase of r (namely dr), if the rate of increase of K

with respect to r were to remain constantly equal to the value which the derivative dK/dr has for the initial value of r. That is $dK = (dK/dr) \cdot dr$!

And here we come to a dead stop; the syllabus definition has its tail in its mouth! It is entirely useless in the setting up of an epitome of the argument A, and it is utterly devoid of suggestiveness; its only use, indeed, is that it enables one to write down such an expression as $dy = 2ax \cdot dx$ in vain pride of precision and rigor.

It is time, however, that our mathematics teachers should realize that mathematics is not merely writing down letters, however great their readiness may be to give a simple explanation of what the letters are supposed to stand for. Ask a young man what he gets when he multiplies 2 dollars per day by 500 days, and he will say, correctly, 1,000 dollars. But if you ask him how to perform such a profitable operation, he will wonder what you can possibly mean by profit in speaking of mathematics! To multiply 2 dollars per day by 500 days means to work hard for 500 days! That is what this particular multiplication means, and nearly every mathematical process rightly understood refers to physical reality in a manner scarcely less definite and exacting. Writing down symbols indeed! The wonder is that any amount of conceited and reentrant logic could make some of our mathematics teachers unashamed in view of what they accomplish in the class room, which is vanishingly small.

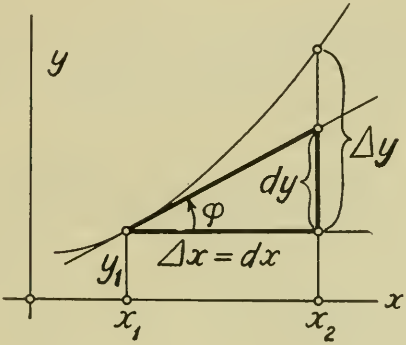
THE PROPER USE OF THE DIFFERENTIAL IN CALCULUS.

BY EDWARD V. HUNTINGTON,

Assistant Professor of Mathematics in Harvard University.

THE RIGHT WAY TO INTRODUCE THE DIFFERENTIAL NOTATION.*

Every time an observant student examines the graph of a function $y=f(x)$ in an interval from $x=x_1$ to $x=x_2$ (see figure), there are three concrete geometrical magnitudes which immediately compel his attention:



(1) The increase produced in the function by the increase given to x; this increase we denote by Δy (called the increment of y);

(2) The increase that would be produced if the curve coincided with its tangent at the point x_1; this increase we denote by dy (called the differential of y);

(3) The slope or gradient of the tangent line; this slope is called the derivative, and may be denoted, for the moment, by $\tan \phi$.

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* The following brief account of the differential notation is essentially that given in the Syllabus of Mathematics, published by this Society. For a fuller account, see any good text-book on calculus.

Of these three quantities, we see at once that $\tan\phi$ depends only on the value of x; Δy and dy, on the other hand, depend also on the increment given to x, which (when x is the independent variable) we may agree to denote at pleasure by either Δx or dx.

All these quantities are definite, concrete geometrical magnitudes, whose existence and importance cannot fail to be patent to any student who uses his eyes. A relation between them is obviously

$$\tan\phi = \frac{dy}{dx},$$

since in any right triangle, the tangent of an angle is "the side opposite divided by the side adjacent." Moreover, if we choose to make Δx vary, so as to approach zero as a limit, then $\lim\,[\Delta y] = 0$, $\lim\,[dy] = 0$, and $\lim\,[\Delta y/\Delta x] = \tan\phi$, this last relation providing us with the well-known method of computing analytically the value of the derivative.

All this is so well known that it seems almost an impertinence to take the time of this Society to present it. And yet, in view of recent discussion of the matter,* I believe that there are two considerations to which it would be well to call attention.

The first is this: *In spite of the fact that all competent mathematicians have long been perfectly clear on this subject, there are still many recent textbooks (chiefly those intended for students of engineering or physics) in which the differential notation is treated in a manner so vague and confusing as to deprive it of all practical value.*

To prove this statement, I beg to cite the following passages from widely used textbooks, all of which have been published since the beginning of the twentieth century.

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* I refer especially to an article by Professors Franklin, MacNutt, and Charles in the present issue of the BULLETIN, which contains a vigorous attack on the Syllabus definition of the differential.

EXAMPLES OF BAD METHODS OF TREATING THE DIFFERENTIAL.

One very common method is illustrated by the following quotations:

(1) J. W. Mercer, "Calculus for Beginners," 1910, p. 50 (in bold face type): "*ds* and *dt* have no separate meanings; *dt* does not stand for a small increment in t, nor *ds* for a small increment in s. $\frac{ds}{dt}$ must be treated as a whole. It does not mean the result of dividing *ds* by *dt*."

(2) D. A. Murray, "Infinitesimal Calculus," 1903, pp. 43 and 49: "The symbol $\frac{dy}{dx}$ does not denote a fraction; it does not mean the ratio of a quantity *dy* to a quantity *dx*. It must be clearly understood that the cancellation of the *dx*'s in the equation $dy = \frac{dy}{dx} dx$ is impossible."

(3) John Perry, "Calculus for Engineers," 4th edition, p. 15: "The symbol for this rate is $\frac{dy}{dx}$. Observe that it is one symbol; it does not mean $\frac{d \times y}{d \times x}$."

(4) Franklin and MacNutt, "Elements of Mechanics," 1908, p. 44: "The symbol dS/dt is one single algebraic symbol, and it is not to be treated otherwise."

These writers evidently do not regard *dx* and *dy* as quantities at all. For them, the symbol $\frac{dy}{dx}$ means $\frac{d}{dx}(y)$, where $\frac{d}{dx}$ is a symbol of operation, and y is the quantity on which the operation is performed. Logically, of course this is a perfectly tenable position. But from the point of view of practical convenience it is hardly defensible. For if all one wants is a symbol of operation, D_x is simpler than $\frac{d}{dx}$ and the chief advantage of the notation $\frac{dy}{dx}$ is entirely lost if we are not allowed to separate the *dy* and *dx*. I can imagine few things more tantalizing to the student than to be obliged to remember constantly that a symbol which has been specially constructed so as to look like a fraction must never be used as if it were one!

A second and more common view of the differential notation is the following:

(5) Geo. A. Osborne, ''Differential and Integral Calculus,'' revised edition, 1906, pp. 68 and 73: ''The differential of any variable quantity is an infinitely small increment in that quantity. Thus dx is an infinitely small Δx, and dy is an infinitely small Δy. An infinitely small increment, or infinitesimal, may be defined as a variable whose limit is zero.''

But this is surely no adequate definition of a differential. For the increment Δy is also '' a variable whose limit is zero ''; hence the definition gives us no criterion by which to distinguish between Δy and dy; and if dy and Δy are the same, there is no occasion for introducing the symbol dy at all. That there is much confusion in the books on this point is attested by

(6) J. W. Mellor, ''Higher Mathematics for Students of Chemistry and Physics,'' second edition, 1905, p. 18: ''As a matter of fact, the symbols dx, dt, etc. are constantly used in place of Δx, Δt, etc.''

A third point of view is illustrated by the following citations:

(7) John Graham, ''Elementary Treatise on the Calculus,'' 4th edition, 1914, p. 25: ''When δt [or Δt] is *indefinitely small, that is, smaller than .000 000 000 1,* it is denoted by dt, and the corresponding increment of space by ds.''

According to this author, a variable increment is to be denoted by Δy or by dy according as it is greater or less than .000 000 000 1! One is left to wonder whether this means one billionth of a millimeter or of a light-year! Scarcely less naïve are the following:

(8) J. W. Mellor, *loc. cit.*, p. 32: ''Our reason is satisfied to reject the differentials when they become so small as to be *no longer perceptible to our senses.*''

(9) W. Watson, ''Text-Book of Physics,'' 1907, p. 27: To measure instantaneous speed, we divide the space by the time, taking the interval of time ''so small that the speed does not appreciably alter'' during that interval.

10) Henry S. Carhart, "Physics for University Students," 1906, p. 11: "Let M and M' be the positions of the particle at epochs t and t'. Then $v = MM'/(t'-t)$ is the mean velocity during the time $t'-t$. [To obtain the instantaneous velocity at the time t] imagine now MM' to be reduced to infinitesimal dimensions, and let its value then be represented by ds. Also let the time of traversing this minute distance be dt. Then precisely as before, $v = ds/dt$."

For these writers, a differential is a quantity which is apparently finite, but so small that whenever it occurs by itself (not in a ratio with another), it may be neglected without "perceptibly" or "appreciably" damaging the result. Such a definition is clearly unsatisfactory; for if this were really what we meant by dx and dy, the results obtained by the methods of the calculus would be only approximately true!

The approximate character of the results of the calculus is indeed sometimes admitted; for example:

(11) J. W. Mellor, *loc. cit.*, p. 14: "The symbol '=,' when used in connection with differential coefficients, does not mean 'equal to,' but rather 'can be made as nearly equal to as we please.'"

Most writers, however, insist that whatever may be said of the method, the results at least are correct. This leads to what I shall call the fourth method of defining a differential.

(12) John Goodman, "Mechanics Applied to Engineering," 1903, p. 556: "It will be seen that if Δl be taken large, error will be introduced, and that the error becomes smaller as Δl becomes smaller, and that it *disappears when Δl becomes infinitely small.*" When this happy state is reached, "we substitute dl for Δl."

In other words, dl is that value of Δl for which the error produced is zero. But a moment's thought will show that the only value of Δl for which this is true is $\Delta l = 0$; for if Δl has any value other than zero, the actual size of the error produced can be readily computed. Hence this definition of dl is equivalent to saying that $dl = 0$! Here at least we seem to be on clear ground! The differential of a quantity is the simplest thing in the world, namely zero!

But hold. Are we quite sure that we understand what these authors mean when they use the symbol 0? Let us listen again to Mr. Mellor:

> (13) J. W. Mellor, *loc. cit.*, pp. 10 and 12: ''I suppose that the beginner has only built up a vague idea of the magnitude of differentials or infinitesimals. They seem at once to exist and not to exist. I will now try to make the concept more clearly defined. In mathematics, two meanings are given to the word zero—*absolute zero* and *relative zero*. Relative zero is defined as an infinitely small or vanishingly small number. For example, we might consider a point as an infinitely small circle. Tersely, relative zero implies that however small a thing may be, its property of growing small without limit is alone retained in the mind.''

Here then is a fifth definition of a differential. It is not an absolute zero but only a ''relative zero''! And to explain what is meant by a relative zero we are asked to consider a point as a small circle whose only property is the property of growing smaller! It is difficult to take such statements seriously; and yet they are by no means uncommon. Thus:

> (14) A. H. Angus, ''Differential and Integral Calculus,'' 1906, p. 15: ''When a quantity becomes indefinitely small, far too small for human, mental conception, we call it infinitely small, and we write it mathematically '0,' called nought, or zero. Thus, as well as denoting what we familiarly call nothing, the symbol 0 is also used to denote a quantity so small that we are unable to distinguish the difference between the quantity and nothing.''

In other words, mathematical zero is directly dependent on the power of our microscopes!

Such are the confusions into which one is led when one attempts to define a differential as an infinitely small increment. One can never tell in advance what a given writer is going to mean by infinitely small. Some writers, as we have seen, mean merely a variable increment approaching zero as its limit, and therefore use dy and Δy quite indiscriminately (as, for example, John Perry, *loc. cit.*, p. 142); others mean a constant magnitude negligibly small, and therefore abandon all claim to accuracy in their results; while others mean either a flat zero, or else one of those '' relative zeroes,'' which at the same time '' exist and do not exist,'' one of those '' ghosts of departed quantities" which Bishop Berkeley so justly satirized in the early years of the science.

Finally, there is a sixth way of treating differentials which is purely abstract and conventional, utterly devoid of any "appeal to sense material, or to the quantitative notions which permeate everyday life." For example:

(15) Franklin, MacNutt, and Charles, "Calculus," 1913, p. 19: After defining the derivative quite correctly as the limit of the quotient $\Delta y/\Delta x$, they introduce the differential, in connection with the equation $\frac{dy}{dx}=2ax$, as follows: "Heretofore we have looked upon $\frac{dy}{dx}$ as a single symbol. *Convenience of notation sometimes makes it desirable to write the equation thus:* $dy=2ax\,dx$. dy is called the differential of y and dx is called the differential of x."

This is obviously the merest juggling. Since neither dy nor dx has been so much as mentioned up to this time as a separate entity, how can the student attach any real meaning to the so-called equation $dy=2ax\,dx$? The guidance of analogy, which doubtless suggested the breaking up of the symbol dy/dx into parts, is just as dangerous here as in the familiar schoolboy method of treating the symbol $\sin^{-1} x$. What the method might lead to, if consistently applied, may be seen in the following parallel:

The angle whose sine is y we denote by $\sin^{-1}y$, the symbol $\sin^{-1}$ being one symbol, denoting an operation performed upon y. For example, suppose

$$\sin^{-1}y=\pi.$$

Now $\sin^{-1}$ looks as if it meant $1/\sin$. "For convenience of notation," then let us write the equation thus:

$$\frac{y}{\sin}=\pi, \quad \text{or} \quad \sin=\frac{y}{\pi};$$

and in this equation, let us call sin the "crust of the π."

The limit of the ratio $\Delta y/\Delta x$ we denote by $\frac{dy}{dx}$, the symbol $\frac{d}{dx}$ being one symbol, denoting an operation performed upon y. For example, suppose

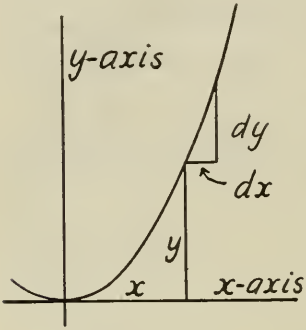
$$\frac{dy}{dx}=2ax.$$

Now $\frac{dy}{dx}$ looks as if it meant $dy \div dx$. "For convenience of notation," then, let us write the equation thus:

$$dy=2ax\,dx;$$

and in this equation, let us call dy the "differential of y."

The parallel is an absolutely true one; each column purports to define a new mathematical symbol, and the method in one column is no better and no worse than the method in the other column.



The authors of course add the usual explanation that "dy and dx may be thought of as indefinitely small increments of y and x respectively"; and on p. 24 they give the adjoining figure, as an illustration of the equation $dy = 2ax\,dx$, which they maintain is "rigorously true." I will leave the reader to determine for himself which of the possible meanings of "infinitely small" these authors probably had in mind when they drew this figure. The contrast between their figure and the standard diagram at the beginning of this article will well repay careful study.

The above quotations, selected almost at random from text-books in current use today, are sufficient, I believe, to establish my first thesis.

THE USEFULNESS OF THE DIFFERENTIAL NOTATION IN APPLICATIONS.

I now turn to my second thesis, namely, that *the orthodox mathematical definition of a differential, as briefly sketched at the beginning of this article, provides precisely the direct and suggestive notation which the workers in applied mathematics require, since it enables one to proceed rapidly and directly to the desired "answer" without the necessity of stopping to put in every step of the reasoning unless one wishes to do so.** In other words, the differential notation stands ready to supply all the "rigor" that may be desired whenever it is wanted; but it does not obtrude its rigor on the attention of anyone who may wish to travel light and cut the corners.

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* This statement is stoutly denied by Professor Franklin, MacNutt, and Charles, but the alleged illustration which they give under the heading "C" is a mere travesty on the Syllabus method which no mathematician would think of using.

The usefulness of the differential in applications depends on the following theorem:† *In all the ordinary problems about the "limit of a ratio" and the "limit of a sum," we may replace Δy by dy, without altering the final result.* Or, briefly: *In all ordinary cases, dy is a good approximation to Δy.*

This theorem of course requires amplification and proof (the proof will be rigorously studied or taken largely on faith, according to the temperament of the student); but when once accepted, it provides one of the most elegant and powerful tools which pure mathematics has ever contributed to science.

For illustration, let us take the following example of the process of setting up a differential equation.‡

A. Complete Form of the Argument, by the Method of Limits.—Let it be required to set up an expression for the derivative dK/dr, where K is the moment of inertia of a circular disk of radius r referred to its axis of figure. Let m be the mass per unit area. Then $\Delta M = [\pi(r+\Delta r)^2 \pi r^2]m = 2\pi r m \Delta r + \pi m (\Delta r)^2$ is the added mass due to the increment Δr. The distance of the added mass from the axis is greater than r and less than $r+\Delta r$; therefore the increment in K lies between $r^2 \Delta M$ and $(r+\Delta r)^2 \Delta M$. Expanding and collecting terms, we find that $\Delta K/\Delta r$ lies between $[2\pi r^3 m + \pi r^2 m \Delta r]$ and $[2\pi r^3 m + 5\pi r^2 m \Delta r + 4\pi r m (\Delta r)^2 + \pi m (\Delta r)^3]$. But both of these expressions approach $2\pi r^3 m$ as a limit as Δr approaches zero, and therefore $dK/dr = 2\pi r^3 m$.

B. Abbreviated Form of the Argument, by the Use of Differentials.—The added differential of mass, due to the increment dr, is $dM = 2\pi r m dr$ [because one recognizes $2\pi r dr$ as a "good approximation" to the area of a narrow circular annulus whose length is $2\pi r$ and width dr].

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† For a more exact statement of this and related theorems on infinitesimals, see the "Syllabus of Mathematics."

‡ This is the same example as that used by Professors Franklin, MacNutt, and Charles.

The distance of the added mass from the axis is r [because one recognizes r as a good approximation to anything that lies between r and $r + dr$.] Therefore $dK = 2\pi r^3 m dr$.

There are no "fallacies" in this kind of abbreviated statement. It differs from the complete statement A only in this respect: In B we use the results of a theorem which is supposed to have been proved once for all, while in A we repeat, for the particular case before us, the details of the proof of that theorem.

Moreover, the attitude of the student's mind toward this process is a perfectly normal and intelligent one. There is nothing mysterious or vague in the statement that "the area $2\pi r dr$ is approximately equal to the area of a certain circular annulus," since $2\pi r dr$ is a perfectly definite area, and the difference between it and the annulus in question, for any given values of r and dr, can be written out at length.

Compare this with such a statement as the following, which the authors above cited are fond of using: "$2\pi r dr$ is the *limiting form* for expressing the area of a narrow circular annulus." What is a "limiting form"? Is it a quantity, or not a quantity? If it is a quantity, how big is it? If it is not a quantity, what right has it to stand as one member of a mathematical equation?

It is this question of the attitude of the student's mind which must be the central question in any discussion of methods of teaching. If the orthodox mathematical method of defining differentials, as sketched above, leads the student to form a definite, concrete picture of what he is doing when he manipulates these symbols—and I am convinced that it does do so—then that is the method which we all ought to teach. If on the other hand any method is presented which compels the student to handle his mathematical symbols in a purely mechanical fashion, not translatable into visual or quantitative terms—and I believe that each of the six types of "bad methods of defining the differential" cited above falls under this category—then such a method ought to be abandoned as a menace to clear thinking and effective progress.

THE CALCULUS WITHOUT SYMBOLS.

BY E. R. HEDRICK,

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It is reasonably easy to state most of the results of the calculus in a form which requires no previous mathematical training and which employs no symbols of any sort, except only English words.

That this is true perhaps passes the belief of those to whom mathematics as a whole and the calculus in particular is only a mass of meaningless letters and formulas. In this paper it is my purpose to demonstrate this possibility on a few examples which are by no means altogether elementary. My hope is that this will tend to awaken a keener interest on the part of teachers in emphasizing the living truths of the calculus at the expense of the pure formalism which too often conceals these truths; and also to inspire present and past students of this subject with a livelier appreciation of its actual content.

To members of the S. P. E. E. what I have to say will not seem strange, except in that it comes from the lips of a professed mathematician. For you are for the most part men accustomed to deal with actual quantities,—with real *things*. You commonly think in the terms I shall use here. It is rather for the many who are not present, whom your society will help me reach, that I speak as it were not *to you* but only under your auspices.

Rates of Change.

Quantities in nature change continually. Those that do not are largely figments of men's imaginations. The changes in quantities are *fast*, or *slow*, or just *middling*. That is, whenever changes occur, we may speak of the *rapidity* of those changes. I say that the total of the rapidities of the changes that are going on all about us constitutes what is called LIFE, if I may use that word not in its biological sense, but as opposed to stagnation.

Thus we say that sugar dissolves rapidly in water. The rapidity of solution decreases as more sugar is dissolved, and indeed the sugar dissolves more and more slowly until no more will dissolve. We say that the rate at which the sugar dissolves steadily decreases and approaches zero.

Or we speak of the growth of a child, or of a tree, or of a nation. Rapidity of growth is interesting, whether it be of a child, of a nation, or of an electric current.

Any intelligent study of such rates of change is and of a right ought to be a chapter of the calculus, whether symbols are used in that study or not. The hydraulic engineer using a mass curve, which actually represents the total rainfall from a fixed starting date, is just as truly employing the calculus as is the statistician when he notices that the slope of a curve which represents the population of a state gives the rate of growth of that population. Neither uses any equations for his curves.

Anyone who speaks of rapidity of change of anything, and makes intelligent comments about it, is discussing the calculus. The test is not that he should use symbols; it is that the comments be intelligent. On this basis, if you accept it, some topics not commonly included in calculus would be included, and possibly some topics ordinarily included would be discarded.

I may observe, for example, without use of symbols, that if the rapidity of change sinks to zero and remains zero, the quantity concerned does not change at all. Thus, in the saturated sugar solution, the amount of sugar in solution remains fixed after saturation occurs. This is the so-called *fundamental theorem* of the integral calculus. I shall use it again later.

Conversely, if a quantity does not change, the rapidity with which it changes is zero. This is the first formula of differentiation.

If several changing quantities of the same kind are put together, the rapidity of change of the whole is the sum of the separate rates of change, if all other external conditions remain fixed. And so on.

Maxima and Minima.

If a quantity is increasing for a time and then begins to decrease its rate of change is said to be positive while it is increasing and negative while it is decreasing. Barring any violent alteration of external conditions, the rate of change must have been zero at some instant before the quantity decreased. Thus the maximum value of a quantity occurs at a time when its rate of change is zero; just previous to this instant the rate of change must have been positive, and just afterward negative.

For example, if the temperature rises and falls during the day, it is clear that the rate of change of temperature is zero at the hottest instant, and also at the coolest instant; the two instants differ in that just before the hottest instant the temperature was rising, while just before the coolest instant the temperature was falling.

This is, of course, a pretty fair discussion, in brief, of the conditions for maxima and minima. As noted, any sudden alteration or stoppage of external conditions is barred.

I do not see what is to prevent my discussing any topic of the calculus in just such a manner. Where am I forced to stop? But one objects that I have not described accurately what is meant by a rate of change. Nothing is easier. I have not done so largely because this one topic is now handled fairly well in several, but by no means all, text-books, in plain English. The amount of a change in a short period of time is actually measurable; the average rate of change during that period is the ratio of the amount of the change to the length in seconds of that period of time. The limit approached by this ratio as the time diminishes toward zero as a limit is what is meant by the (instantaneous) rate of change.

To my mind this notion of rate of change (at an instant) is quite common even with untrained persons; certainly it is part of the everyday experience and usage of most cultured persons of intelligence.

But another says that I have omitted to mention many a formula and many a functional sign. As for the signs, I have for to-day explicitly disavowed them. As for the many, many facts that may be intelligently stated about rates of change, I shall certainly not attempt to rehearse them all now, since there are to be other exercises this week. The question is, *which one* would you have me do? Which one can I not state in plain English? This is a challenge. And if there be an intelligible fact about rates of change which cannot be expressed in the English language, I will have none of it in a course on the calculus.

What is Integration?

I should before closing at least refer to integration. The most vital point is that the knowledge of the rate of change of a quantity together with the knowledge of its original value, suffices to completely determine the value of that quantity at any time.

How do I know that this is accurately true? Why, because two different quantities that have the same rate of change surely maintain a constant difference, since the rate of change of their difference is zero. This proves, then, the most crucial fact about integration. In the proof I have used the "fundamental theorem" referred to above.

All that remains to be done is to discover by some device one single expression which has the given rate of change, since I have shown that the desired result must differ from it at most by a constant. This trick of discovery of a quantity that has a given rate does necessitate a ready knowledge of the rates of change of a grand variety of formal expressions, if one is to make quick and accurate guesses of quantities that have given rates of change.

Relation of Calculus and Algebra.

Integral tables can be purchased which help to supply this need. It is certainly true that a knowledge of algebraic symbols is quite necessary to intelligently read these tables. But this does not violate my principal contention, for it is equally true that a knowledge of algebra is quite necessary to read intelligently almost any modern set of tables; emphatically it is to read any modern engineers' handbook! The occurrence of the algebraic formulas is not especially due to the calculus and its ideas. Their occurrence is rather the *cause* for the occurrence of any formulas in the calculus. But for the fact that scientists do use algebraic formulas in their work, the *principles* of the calculus would all remain intact and without any formulas whatever.

Thus, when a scientist does happen to need no formulas, as in the case of the hydraulic engineer in his consideration of rainfall estimates, the calculus does not impose any formulas upon him. It is a fact, for example, that the property that the derivative of an integral is equal to the integrand is used by these engineers without the intervention of any formulas, in that they notice that the slope of the mass curve gives the actual rainfall.

I have spoken largely of time-rates. But rates of change with respect to other basal quantities than time are common enough, even in everyday experience of the non-mathematician. Thus the length of a metal bar changes with its temperature. The rate of change of length with respect to temperature change is just as instinctive as is a time-rate.

We might indeed speak of the rate of change of the length with respect to time, that is *per second*, and quite distinctly of the rate of change of length with respect to temperature, that is *per degree Fahrenheit*. If we know also the rate of rise of temperature per second, it is easy to see—and quite easy to prove—that the rate of change of length per second is equal to the product of the rate of change of length per degree and the rate of change of temperature per second.

The general rule follows readily; it is the so-called rule for differentiation of a function of a function, and is quite formidable to many when stated in symbols, with no concrete explanation of its significance.

Of course I have told you nothing new. I did not wish to do so. My desire was only to maintain that the fundamental ideas of the calculus can be stated without recourse to any symbolism, and are in themselves quite free from symbols of any sort. I have challenged the production of a single fundamental fact which contradicts this thesis.

Knowledge of algebraic formulation is desirable for scientific work in engineering. Obviously no man can claim to have any adequate idea of engineering if he cannot understand formulas and algebraic symbols. Laws of nature seem awkward without such formulation, and any handling of these laws is at best clumsy without algebra. I have admitted freely that this means that these same facts and laws of nature must be dealt with in the calculus by means of symbols. Just as no engineer is worthy of the name who knows no algebra, so no calculus wholly without symbols would be adequate for the demands of science. Courses in calculus should contain a very great amount of formal expression and algebraic symbolism. My thesis is not that the calculus cannot be *applied* to formalized expressions, for such a claim would be ludicrous. My claim is that the fundamental ideas of the calculus are not in themselves formalized expressions, and that the handling of algebraic expressions in the calculus is to be regarded as an *application* of the principles of the calculus rather than as its true subject-matter.

The principles of the calculus without symbols ought to be made vividly clear to every student of engineering. There are evidences that the same knowledge would not be amiss in purely academic quarters.

Discussion of Mathematics Instruction.

Dr. T. H. Gronwall: I wish to present the point of view of the practical engineer, obtained during a professional experience covering several years prior to taking up instructional work which I have recently done at Princeton.

The main business of mathematics teachers is to instill into the students the faculty of attacking unfamiliar problems judiciously. The teaching of mathematics falls short of what it should be. I believe that one of the chief shortcomings results from the neglect of approximations.

For instance, take an equation involving an error of observation which probably cannot be less than a certain percentage. It is obviously useless to expect a degree of accuracy greater than set by the errors of observation. Very often a student performs much labor which could be avoided if he had a clear understanding of how much an error in a given quantity will affect the final result. An important question to settle is "how few decimals can be used without reducing the degree of accuracy below the allowable limit?"

It would be an excellent thing in connection with the study of some machine in a course to give particular attention to the graphical representation of the functions involved in the operation of the machine and to graphical solutions of many of the equations. In connection with these calculations, graphical integration is also very helpful and instructive.

Among the fundamental mathematical processes Taylor's theorem is one of the most important. Problems illustrating its use should not be the kind in vogue some years ago, but should be couched in a sufficiently practical way to indicate how many terms should be employed and what is the effect of using more or fewer terms. Another fundamental subject is the Fourier series. The engineer does not care about some of the more advanced problems, as they are not of interest to him, but to give a good group of harmonic analysis, Fourier's series should be taught. It is very useful in electrical problems.

Professor V. Karapetoff: From the fact that the question of teaching mathematics was put on our program we have to conclude that the teaching of mathematics is not satisfactory to those who teach engineering subjects. There appears to be some belief that the trouble lies in the way in which the fundamentals are presented: that if we finally get the student to understand the difference between dx and Δx, all of the difficulties will vanish. This may be so, but I doubt if there is such a simple panacea.

The present discussion is somewhat like that on the best way of grinding a tool, or on its best shape, when those doing the grinding do not know what the tool is to be used for. If the task of grinding or shaping is conducted in the light of the purpose for which the tool is to be used, ninety per cent. of all the difficulties and of differences of opinion would vanish.

Instruction in mathematics can be improved by improving various factors. I can think of three factors which prevent or hamper complete success in teaching mathematics to engineering students, namely: (1) Inadequate preparation in mathematics taught in the high schools. As compared with the work of high schools in Europe, our schools do not do nearly as good work. Perhaps, if the female high school teachers in mathematics were replaced by men we would have better success. (2) In the freshman and sophomore years in colleges, men who do not understand, and who do not claim to understand ideas and problems in engineering, teach young men how to work mathematical calculations in a way presumed to be the best for their engineering studies. (3) Teachers in engineering subjects are not, as a rule, good mathematicians.

The result reminds me of the fable of a lion who was a king over certain animals, and who had a little lion heir apparent, who had to be schooled tnd trained to take care of the kingdom when it should fall to him. The old lion had an idea that only another king could teach the young lion the necessary tricks, and so he sent the whelp off to be taught by an eagle. Among other accomplishments, the eagle taught him to fly. Of course he did not succeed, and in the meantime the pupil failed to learn how to manage his expected kingdom. It is so with the teaching of mathematics, and I am afraid that the time will come when colleges of engineering will say: "We are going to teach mathematics in the way we want it taught and under our own jurisdiction." This will come because there is no reason for giving abstract calculus to men temperamentally unfit to take it, but who will make reasonably good engineers.

There is no reason why teachers of engineering should be poor mathematicians. They must not say, "Well, I do not remember whether the derivative of log x is one over x or something else: I had my calculus so long ago." It is sometimes even a matter of pride with a teacher who plays the part of a practical man to say, "I do not know what the derivative of sin x is, nor do I care what it is." We, as teachers of engineering, should be ashamed of our shortcomings in mathematics, and not brag of them. Then our students will have more respect for mathematics and more interest in it.

Dr. William Kent: A is reservoir of unlimited instructional energy, H represents the machinery and the method for converting a fraction of this energy into useful work at W, the student's mental storehouse. C is the current flowing from A. Part of it overflows at O, part enters the hopper at H, part leaks out at L, part is converted into work, W, and the rejected material without available energy escapes at Y. The formula of the machine is $I = E/R$ in which I is the current in amperes, or educational units of currents, E is the electro-instructo-motive force, and R is the resistance. The resistance in this machine varies inversely as the area of the conduit, or the student's mental caliber, and it is increased by rugosity or lack of preparation and of polish by use, and also by obstructions, such as "gee-pounds," "slugs," "concepts of mass" and other rubbish. In order to increase the value of I, according to the formula, E must be increased or R decreased. Increasing E involves the danger of destruction

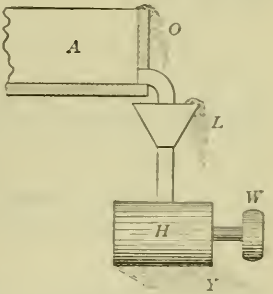

FIG. 1.

of the conduit, as it is structurally weak, or of increasing the leakage. What should be done to decrease R by removing the obstructions and something down the rugosities? It is advisable also to restrict the flow from the reservoir A to the capacity of the hopper, so that there will be no waste by overflow.

The efficiency of the machine, of course, is W/IE in which W is the input and IE output. $IE - W$ represents the wasted energy.

Professor G. R. Chatburn: I was brought up to consider dy/dx as a fraction. Our calculus textbook stated that if a velocity became constant at any instant, the distance passed through in the next instant would be the differential dx, no matter what units of time were used. Take an equation in which dy represents growth in the Y direction and dx growth in X direction. This is a true algebraic equation and it may be divided throughout by dx or dy. Consequently there will be no difficulty in writing, say,

$$dy = 3x^2dx$$

instead of

$$\frac{dy}{dx}dx = 3x^2\frac{dx}{dx}dx.$$

Likewise, no special theorem is required to be able to say

$$\frac{du}{dx} = \frac{du}{dy}\frac{dy}{dx}, \qquad \frac{du}{dx} = \frac{\frac{du}{dy}}{\frac{dx}{dy}},$$

all being algebraic identities.

Professor E. J. Berg: Referring to Dr. Kent's diagram I am not sure that it would be wise to reduce the resistance. It would be better to increase the electromotive force. At Union College we try not to reduce the resistance but to increase the electromotive force, to overcome the resistance.

In my twenty years of experience with the General Electric Company I met graduates from almost every American college, and noticed that they did not make use of calculus, even if they understood it I noticed that they invariably tried to solve problems by means of algebra or some other, often crude, method, and concluded that the fault lay with the mathematical departments of the different institutions. I am now convinced that it does not. If the teachers of engineering would show the students the great advantages of the use of calculus and the wonderful generalizations that can be made by its use, the students would jump at the opportunity to improve their mathematical knowledge.

At the University of Illinois we gave a reward to the senior students who secured grades above 90 per cent. The reward was that they could take an advanced course in partial differential equations, and we found it difficult to find room for the students entitled to this privilege.

At Union College senior electrical engineers will from next year on take a course covering Byerly's Fourier's series, spherical harmonics, etc. I find that the difficulty is not to interest students in advanced mathematics, but is to make them do something else when they get a taste of mathematics. Graduate students are willing to work from eight o'clock in the morning until ten at night on advanced mathematics. These men are given problems of general nature. When, however, they find that the same fundamental equations apply to all kinds of problems, they are likely to lose interest in the electrical problem, they begin to generalize on their own initiative and become so enthusiastic that it is difficult to get them to write their theses.

The engineering department should not blame the mathematical department for students' shortcomings. The fault lies nearer home.

Referring now to the second part of the paper, we consider that our main object is to produce men in every sense of that word. Thus, I feel that the so-called liberal and scientific courses are quite as important as the engineering courses. The Union College curriculum involves more classical study than is customary in technical schools. Many teachers agree, of course, that this is desirable, and all agree that the subject matter is less important than the cultivation of the mind. The students must learn to think and to be accurate in their thinking: accurate and efficient. They must also cultivate a taste for general reading. To accomplish this at Union, a course is given in electrical engineering in which no text-book is used. The students take notes and supplement them by outside reading. The students are given a minimum of class-room work and maximum of home work. Assume, for instance, that we are taking up a phase of electrical engineering which will rquire two weeks time. We first explain the physics and the mathematics necessary, and then outline the problems to be solved. The students apply these principles and are surprised and pleased to find how they are able to "discover" and "invent" devices from the equations, and begin planning how to adapt them to practice.

We give them a condensed bird's-eye view and tell them to read such books as Franklin's, Jackson's, Russell's, Steinmetz's and, in the case of graduate students, Jean's, Webster's, Maxwell's, and those of other writers in whom they are sure to be interested. We are very particular to have laboratory work hand-in-hand with the work in theory, and to teach the students the value of neat work, and neat representation, by curves. We lay great stress on curve plotting, believing that by this means the equations are most intelligently connected with physical facts. The students learn to express the result of their work and to check its accuracy.

As we have no text-books, the student must listen attentively to the lectures. He cannot think of baseball and comprehend what is being said at the same time. In consequence he soon learns to pay strict attention and learns to listen attentively for three or four consecutive minutes.

Professor Edward Robinson: Dr. Kent made a very interesting statement of the present methods of teaching engineering. His diagram expresses exactly the situation. The resistance factor to which he refers can, however, only be changed by changing the elementary school instruction.

Now some teachers can exert more electromotive force than others, and can produce correspondingly greater results. But the whole idea of instruction implied by the electromotive force and resistance illustration is wrong. The development of the student is a growth from within. We cannot make corn grow by pouring excess water upon it, or by any other external means. Sunlight and air furnish conditions under which the corn grows from within, not from without. It is so also with the student. Professor Berg has illustrated in the methods in use at Union College, the true ideal of growth. He gives some lectures on fundamental principles, and then allows his students to discover for themselves the application of these principles. They get a fundamental idea, and its various ramifications are worked out with the aid of mathematics by the students. They can do this. I have had that fact illustrated in the case of my own small boy. I tried for some time to get him to work with a hammer and a saw, but he showed no interest in the operation. Two years later I found him with the tools in hand and offered to show him how to use them. He replied, "I don't want you to show me. I want to learn it myself." Another time when I tried to teach him to swim, he would have nothing to do with my instructions, but after a while began to take a few strokes on his own account and it was not long before he was swimming.

I consider Professor Berg's remarks one of the most suggestive contributions that we have had here. His methods are in a new direction. He has called attention to the fact that while the student is in college he requires guidance and a little help. He will take the tools acquired in college in his hands when he needs them after he has left college and he will be able to use them.

Professor L. A. Hazeltine: Professors Franklin and Huntington have defended their respective positions with vigor. The former refers in his conclusion to the "conceited and reëntrant logic" presumably of his opponents; while the latter includes "all competent mathematicians" and all "good" text-books on his side. What is most needed in discussing this subject of teaching calculus is coöperation. My endeavor in the following remarks will therefore be to examine the points of disagreement among the various methods and the objections to each, and to outline a method which purposes to answer these objections.

As Professor Franklin points out, the question at issue has to do only with methods of notation and of explanation; for all proposed methods will invariably lead to the same conclusions if employed as intended by their proponents. and therefore all may be called "correct." Moreover, there is no longer any doubt as to the utility of "limits," of "rates," or of "infinitesimals." The matter is really one of psychology. both of the teacher and of the student. Some minds have strong intuitive powers while others make up for lack of intuition by their ability to follow the abstract reasoning of others. The criterion of the best method or combinations of methods is that of pragmatism. By what means can the fundamental ideas of the calculus be given to the greatest number of students with the least effort?

The differences in the various methods of introducing calculus hinge on the significance given to the derivative dy/dx. I am able to distinguish only three essentially different ideas in regard to this symbol which I shall take up in succession.

According to the first idea. dy/dx is a compound symbol representing the limit of a fraction, but is not a fraction in its own right. This is well characterized by Professor Huntington when he says that it rests on "a perfectly tenable position . . . but from a point of view of practical convenience it is hardly defensible" and that "the chief advantage of the notation dy/dx is entirely lost if we are not allowed to separate dy and dx."

According to the second idea. dy/dx is the quotient of one infinitely small (or infinitesimal) quantity by another. Professor Huntington finds five forms of this method and objects strongly to all. reserving his choicest sarcasm for that of Professor Franklin. I agree that many of his quotations are not happily expressed—*especially when torn from their context*—

but the ideas on which they are based seem to me to be reasonable and useful. The criticisms of this method seem to be directed against the apparent indefiniteness of "an infinitely small quantity," giving rise to the fear that algebraic transformations of such quantities will not be valid. I believe, however, that the student can "see" these infinitesimals as readily as he could "see" negative quantities, fractional exponents, imaginaries, etc., when these were new; for "seeing" merely means "getting used to," coupled with the feeling (to be developed by the teacher) that the results will be useful and consistent with his previous knowledge.

According to the third idea (that of Professor Huntington, "all competent mathematicians" and "good" text-books) dy/dx is the constant quotient of finite variables, each of which approaches zero as a limit while dx remains equal to Δx, the increment of the independent variable. Professor Franklin justly complains of the "awkwardness" of this method. By it we are compelled to start with finite increments Δx and Δy of the independent variable and its function respectively; then to let these approach zero together, their quotient varying; next to determine the limiting value of this quotient; and finally to find finite values dx and dy so $dx = \Delta x$ and so that $dy/dx = \lim x = 0 \Delta y/\Delta x$. It will be noticed that this notation is not symmetrical, dy not being equal to Δy, so if we change the independent variable, dx and dy (or else Δx and Δy) must assume new values. I believe, however, that this method involves more serious difficulties than these. Professor Huntington's "infinitesimals" and "differentials" are *finite* quantities which approach zero as a limit. In the new Standard Dictionary, on the other hand, there will be found the following definitions: "*Infinitesimal*—infinitely small; denoting a quantity conceived as continually diminishing, so as to become less than any other quantity having an assigned value"; "*differential*—an infinitesimal difference between two values of a quantity: indicated by the symbol *d*." My own experience indicates that the use of Professor Huntington's method encourages students to mix infinitesimals and finite quantities together in ways that are deplorable. I do not believe that he can induce engineering teachers and others not professed mathematicians to depart from current ideas and definitions so far as to accept infinitesimals which are not infinitesimal and differentials which are not differences.

My suggestions of a procedure in introducing calculus, which attempts to embody the best in the various methods, is as follows: After developing the notion of variables, functions, and their (finite) increments, introduce the idea of the *limit*. Define a derivative as the limit of the ratio $\Delta y/\Delta x$, but do not use the notation dy/dx at this time. Explain that a derivative is the mathematical expression for the physical idea of a *rate*. Deduce the expressions for the derivatives of the common functions, employing the limit notation throughout. Show that a derivative is a function of the independent variable.

Then, independently of its application to increments, introduce the idea of infinitely great quantities, or *infinites*, and infinitely small quantities, or *infinitesimals*. Treat these as ordinary algebraic quantities, with the addition of certain relations due to their natures: namely, that an infinitesimal added to a finite quantity does not change the value of the latter, that a finite quantity divided by an infinitesimal is infinite, etc. Explain the *order* of infinites and infinitesimals, and that the quotient of two infinitesimals or of two infinites of the same order is finite. Illustrate these facts by simple examples of indeterminate forms. Recognize that the idea of an infinite or infinitesimal implies the approach to a limit and is relative rather than absolute. Recognize also that infinitesimals of higher orders are not really "neglected" but are omitted because for the problem in hand they are zero.*

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* In spite of Professor Huntington's scorn there *are* such things as "relative zeros," whether this designation is desirable or otherwise. We should not be afraid to say that an infinitesimal quantity is equal to zero; for we commit no error in substituting zero for an infinitesimal term in an equation, though in so doing we make the equations true only to the next lower order of infinitesimals and so may destroy its usefulness. This, however, is proper food for the mature mind and should be given to the beginner with caution.

Then define a *differential* as an "infinitesimal increment." Deduce the expressions for the derivatives of the common functions, employing the differential notation throughout. Emphasize the exact parallelism of the deductions by the two notations and the fact that they are precisely equivalent, any expression in the differential notation being transferred to the limit notation by changing d and $\int$ to Δ and Σ respectively, and prefixing the abbreviation "lim."

As an example of the method outlined above, let us consider the derivative of the exponential function a^x. This function should first be plotted by the students (for more than one value of a) by the use of a table of logarithms, and its essential property of having its ordinates in geometrical progression when its abscissas are in arithmetical progressions should be emphasized. Its derivative is expressed as

$$\lim_{\Delta x \longrightarrow 0} \frac{\Delta(a^x)}{\Delta x} = \lim_{\Delta x \longrightarrow 0} \frac{a^{x+\Delta x} - a^x}{\Delta x} = a \lim_{\Delta x \longrightarrow 0} \frac{a^{\Delta x} - 1}{\Delta x}.$$

The graphs (immediately adjacent to the vertical axis) show that the fraction in the second member has a finite limit which is a function of a and which may be donated by m:

$$\lim_{\Delta x \longrightarrow 0} \frac{\Delta(a^x)}{\Delta x} = ma^x.$$

The value of m corresponding to the values of a employed in the graphs should be computed; and it should be observed that as a varies from 1 to ∞, m varies continuously from 0 to ∞. Hence there is a particular value of a for which $m = 1$. Denoting this value by e, we have

$$\lim_{\Delta x \longrightarrow 0} \frac{\Delta(e^x)}{\Delta x} = e^x.$$

We are now in a position to find the relation between m and a for we have

$$a^x = e^{x \log_e a}$$

and hence

$$\lim_{\Delta x \longrightarrow 0} \frac{\Delta(a^x)}{\Delta x} - \log \text{“}a\text{”} \lim_{\Delta x \longrightarrow 0} \frac{\Delta(e^x \log_e a)}{\Delta(x \log_e a)}$$

$$\frac{d(a^x)}{dx} = \frac{a^{x+dx} - a^x}{dx} = a^x \frac{a^{dx} - 1}{dx} = ma^x,$$

$$a = e,$$

Hence

$$m = 1,$$

The approximate value of e may thence be obtained from the graphs; the exact value should be computed from the series for "e^x," which should be derived by Maclaurin's theorem. It will be seen that this procedure makes unnecessary a knowledge of the binomial theorem, which may, therefore, be developed later by Taylor's theorem. The differential notation for the above equations is given below without repeating the verbal explanation:

$$\frac{d(e^x)}{dx} = e^x,$$

$$a^x = e^{x \log_e a},$$

$$\frac{d(a^x)}{dx} = \log_e a \frac{d(e^{x \log_e a})}{d(x \log_e a)} = \log_e a \cdot e^{x \log_e a} - \log_e a \cdot a^x,$$

$$m = \log_e a.$$

In regard to the *graphical representation* of infinitesimals, it should be borne in mind that they cannot be drawn accurately, and were this possible, they could not be seen! Exactly the same objection applies, however, to a geometrical representation of *points* and *lines*, for these have no width nor thickness. We may draw small triangles to stand for infinitesimal triangles, just as the ordinary spots and bands stand for geometrical points and lines. This is a common procedure and is followed by Professor Franklin in the figure instanced by Professor Huntington. When it comes to the *actual measurement* of a derivative, of course, a tangent must be drawn; this also is a common procedure and is followed by Professor Huntington in his cherished figure. We may even label the sides of the triangle under the tangent "dx" and "dy," indicating that they are *proportional* to these infinitesimal quantities, just as we commonly label the sides of a right triangle "cos θ," "sin θ," "l," to indicate their proportionality to those trigonometrical quantities. Will not Professor Huntington be satisfied with this concession which so closely approaches his own procedure?

In regard to *setting up a differential equation*, I have no improvement to offer over the methods used by Professors Franklin and Huntington in their example of the moment of inertia of a circular disk. Their "complete forms" A (employing the limit notation) are identical except for insignificant verbal differences; and their "abbreviated forms" B (employing the differential notation) are strikingly parallel in thought, while the difference in form is too slight to be regarded except by the hypercritical. I prefer Professor Franklin's expression of B, however, and regret that he has not the courage of his convictions for he intimates the presence of fallacies which are really non-existent. Professor Huntington seems here to abandon his "finite infinitesimals"; for he specifies that the annulus is "narrow," and his expression for its area is true only when it is infinitely narrow. If—as seems the case—we have no real difference of opinion here, is it not reasonable that other formal differences can be overcome?

I believe that for the sake of the student it is very important that the teachers of calculus and the teachers of other subjects that involve calculus come to an agreement on the best method of presenting the subject. I, therefore, beg to suggest that a committee of this Society, including representatives of opposing methods, be asked to thresh out these methods and endeavor to settle amicably on one acceptable to all.

Professor C. Frank Allen: Dr. Kent enunciated a very important principle in stating that we should learn to apply an abstract principle under different circumstances. It is equally true that one should know where a principle or proposition applies and where it does not apply. In making his diagram he has made the unfortunate mistake that this applies to the work of teaching, when it applies practically to the work of this Society.

In that figure I do not quite understand the distinction between "flow" and "waste" and I would suggest the use of the word "vacuum" for "waste." During the proceedings of the past two days I have felt that the emphasis was being placed on teaching rather than on education. Education means "drawing out," the vacuum principle applied. Dr. Kent's diagram implies an attempt to push the thing through, whereas pulling is more effective. It is not wise to try to push a rope when you can pull it much better.

President F. W. McNair: I am in hearty agreement with Professor Allen on the point he has just made, that too many of us become absorbed in the effort to give to the student, and that we are apt, unconsciously, to lose sight of the fact that whatever the student gets he must acquire for himself.

In reference to Professor Berg's interesting remarks I would say he is dealing with junior and senior students, while the great difficulty seems to confront us in the freshman year, rather than later. If we are to do the student much good, we must reach him in his first year, and influence him as much as we can. In the papers on teaching the student to study, what seems to me his greatest difficulty has not received the attention which I expected for it when I read the titles of the papers.

As I meet young men when they first come to college, I find about one in fifty able to study efficiently. Their great difficulty is in concentration. They lack ability to pick up a subject at a given time, and to think about it continuously for any considerable number of minutes. Teachers cannot make over a man of that sort into one who can think steadily about a subject on which he chooses to set his mind, but I believe we can do much to help him make over himself. In my daily work I hear something of student troubles. I meet young men in their first year who are in difficulty, and who are often discouraged. Sometimes one feels an instructor has been unfair, sometimes he is convinced that he is hopelessly dull. Very frequently I find that the man is unable to study efficiently simply because he cannot control his mental vision for any considerable length of time. I have had the pleasure of helping such men by pointing out to them the actual conditions which they must overcome, usually for giving an imaginary description of their attempt to get a lesson, say in geology. I have seen more than one man's face light up as the true condition of affairs dawned on him, and have heard him say "Yes, that is right. I take up my book, but after reading but a short while I find I am thinking of something else." To make such a man comprehend the difficulty is to place him on the way to overcoming it.

Another way to help certain students is to point out the lack of sufficient will power. They cannot turn resolutely from the exciting game or the enticing magazine story to the quiet, and not always attractive, study. To point out to a student this fact, and how it handicaps him in college work will often help him to overcome this reluctance to leave that which is pleasant, and, for the sake of the ultimate gain, turn to that which is not pleasant.

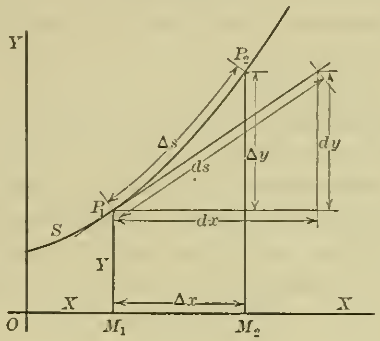
Just a word about the calculus controversy, which I have enjoyed very much. My interest in the subject led me years ago to present to this Society a paper on teaching the calculus to engineering students. The speakers here have presented some of the ideas for which I then contended as an active teacher of the subject. Professors Huntington and Franklin are aiming at the same target, and their differences are not very considerable. I am pleased that this discussion which I tried to start many years ago has at last become a living thing. It is good for engineers and mathematicians to talk this matter over, and for each to confess that there are difficulties for which they themselves may be responsible.

Professor W. J. Risley: It seems to me that we are in a fair way to get something done. The engineer comes to the mathematician and says, ''You have done a poor piece of work''; the mathematics teacher says to those in high school, ''You have done poor work''; and in turn the high school teacher says the same thing to the grade teachers. That, I believe, nails the blame where it belongs. If we had a little less ''soft soaping'' and more stiffness put into the most elementary teaching we would be better off. If the child nowadays got what we studied as old-fashioned mental arithmetic some of the same principles applied in our advanced teaching would help matters considerably.

It is not necessary for the engineers to take over the teaching of mathematics, for they would make a poor job of it. Too many of them are in the habit of telling their students, ''You don't need this,'' or ''You don't use that in practice.'' You can draw a circle around the man who teaches in that way. Dr. Kent said, ''I would teach so many days or weeks of calculus, and the rest I would leave open.'' Professor Berg says, ''Students should have the Fourier series.'' The civil engineer cares for little trigonometry except the solution of triangles and projections, and engineers have told me that they could write out an adequate 15-day course in trigonometry. But in the present discussion we are on the right track; we are getting together.

We need to broaden our views as mathematics teachers, engineers and engineering instructors. The engineers should talk about the mathematics they would have taught, should present the principles in mathematics which they would like to have their students know at the end of the sophomore year. It is not possible always to put in the technical work on the Fourier series and finish it up at the second semester of the second year, with the present preparation of the entering student. It would be helpful if the engineering teachers would outline the mathematical characteristics that would help their students when turned over from the mathematics department to them.

Professor R. G. Thomas: I wish to commend the treatment by Professor Huntington on the differentials dy and dx and the ratio or fraction dy/dx in his article in the June BULLETIN, and in the Syllabus of Mathematics. I would suggest, however, that it should be brought to the attention of beginners in calculus that differentials may or may not approach zero as a limit; that is, may or may not be regarded as infinitesimal.



The increments of the variable are defined as the actual changes and the differentials as the changes that would occur if the changes of the variable were or should become uniform. In the figure the Δy, Δx and Δs are the increments. and dy, dx and ds are the differentials. It should be noted that the differentials may be finite.

In the case of velocity, when it is stated that the velocity of a train at any instant is 30 miles per hour $\frac{ds}{dt} = \frac{30 \text{ miles}}{1 \text{ hour}}$.

Here s represents space or distance, and t represents time, while ds and dt are finite quantities.

The defining of differentials as the uniform changes in the variable is not consistent with the definition of the derivative as a limit when $\Delta x = 0$, of $\Delta y/\Delta x$, *i. e.*, dy/dx.

When integration is regarded as summation, then differentials may become infinitesimals, and are perforce regarded as such. It should be emphasized, however, that differentials may or may not be infinitesimals.

Professor Huntington: It is perfectly possible to define dx and dy as *any* two quantities whose ratio is equal to the value of the derivative. I prefer, however, to retain the definition which allows us to think of dy and $\triangle y$ as approximately equal when $\triangle x$ is small.

Professor E. F. Coddington: Professor Hedrick has told us how to introduce the calculus without the use of symbols. It is necessary for the teacher of mechanics to make use of this method and to combine it with the use of symbols. If he is going into any elaborate discussion of these symbols in applying calculus to mechanics, he will not get very far. In teaching engineering students, we do not want to magnify the difficulties, and we do want to introduce these calculus symbols in the simplest manner possible. My method is to teach them as differentials—little pieces of the real thing. Allow me to present one or two illustrations. Take the following equation where V represents the volume of a sphere.

$$v = \tfrac{4}{3}\pi r^3.$$

Differentiating, we have

$$dv = 4\pi r^2 dr,$$

where dv is the differential increment to the volume of the sphere. It is made up of the product of the surface of the sphere and the thickness of the increment. Of course, the students are told that this expression cannot be used to find the volume of a spherical shell of finite thickness. They should, however, be shown that this expression can be used to find the volume of a spherical shell to a fair degree of accuracy, and often to the accuracy desired, when the thickness of the shell is small in comparison with the radius of the sphere.

Put the calculus with symbols in the simplest way possible so that the student can see what you are doing. Do not lay too much stress upon rigid demonstration.

Professor Huntington: I want to dispel one impression that I may have made, as I did not have time to come to the second point of my paper, which is on the usefulness of the differential notation. I have no more interest than Professor Franklin or any other teacher of engineering students in cumbering the ground with technical details of mathematical rigor that will not be of service to the men. The second part of my paper indicates this. What I wish to emphasize is that the modern mathematician's way of handling the differential possesses all of the celerity and the manipulative edge which is so rightly demanded in Professor Franklin's paper; if it adds to that the further element of logical defensibility, this is a feature which at least need not be laid up against it as a crime.

Professor Franklin: Our attention, in connection with the teaching of calculus, has been directed almost wholly to other matters than those at present under discussion, and we must confess that we are surprised at the prevalence of hopelessly bad logic in mathematical text-books, as shown by the numerous examples given by Professor Huntington. We had not realized the extent of the confusion in this matter. We believe that even an elementary science text must be exactly correct and impossible of misinterpretation. It seems to us that this ideal is entirely feasible in mathematical texts, and nothing short of a complete realization of it should ever be tolerated. This, as it seems to us, is Professor Huntington's main contention and in which he is wholly right. Also we admit the correctness of the Syllabus definition of a differential and we admit that the discussion of the differential in our calculus is vague and apt to be misleading. We intend to adopt the Syllabus definition in the second edition of our book. We are convinced, however, that the Syllabus definition cannot be intelligibly used in complicated statements relating to the great majority of physical problems, and in those portions of our calculus which have to do with physical applications we intend frankly to use the mode of expression which is common among writers on applied mathematics and speak of a differential as a "vanishing increment." We intend to do this because we believe that it is necessary to use a suggestive style even in a treatise on calculus, and it is from this point of view that we gave our epitome of the strict argument of differentials on pages 16 and 17. We insist that this epitome is not a travesty on the Syllabus definition.

Any definition of a differential which tends to relieve the student of the necessity of thinking of the details of the argument of limits in the study of calculus is, in our opinion, undesirable in a permanent plan for the student to follow. It seems to us that the Syllabus definition does have this tendency, whereas the notion, more or less vague it must be admitted, of a differential as a vanishing increment does actually call to mind the essential steps of the argument of limits.

But few people realize that the notion of a differential, more or less disguised, lies at the basis of nearly every idea and every definition in physics. A good example is afforded by Coulomb's law of attraction and repulsion of magnet poles. As usually stated this law involves the consideration of what are called "concentrated" magnet poles, the force of attraction of two such poles being given by the equation:

$$F = \frac{m'm''}{r^2},$$

where m' is the strength of one concentrated pole, m'' is the strength of another concentrated pole, and r is the distance between the poles. In fact m' and m'' in this equation are differentials, and the proper form in which to write the equation is:

$$dF = \frac{dm' \cdot dm''}{r^2}.$$

What we maintain is that to attempt to establish a clear idea of the concentrated pole (a differential) on the basis of the Syllabus definition would be hopeless. It is impossible to formulate a statement covering this matter which would be intelligible to any young man.

Another illustration of the use of the differential in physics is afforded by the idea of the velocity of a fluid at a point. This idea to be realistic must refer to the velocity of a small particle of a fluid, and this small particle of the fluid (a differential) is to be thought of as having a uniform velocity. It would be impossible to formulate a verbal definition of the velocity of a fluid at a point which would conform to the Syllabus definition. Let one attempt to translate the phrase "if the curve coincides with its tangent" so as to make it cover the idea of uniformity of distribution of velocity throughout a small particle of the fluid!

The idea of a differential enters into physics in two ways: 1st, in the study of phenomena which depend upon conditions which vary in time it is necessary to direct the attention to what is taking place at this or at that instant, or in other words, to direct the attention to what takes place during very short intervals of time, or, borrowing a phrase from the photographer, to make a snap shot of the varying conditions; and 2d, in the study of phenomena dependent upon conditions which vary from point to point in space, the attention must be directed to what takes place in very small regions. It is absolutely necessary for the physicist to think of intervals of time which approach zero as a limit and of regions of space which approach zero as a limit, and to consider the associated variations of dependent variables. We believe that the term, "vanishing increment," brings these matters most clearly to mind.

The extreme emphasis we have employed in certain portions of our paper (if we may be permitted to use an innocuous word to call to mind that which must be offensive to many of our friends) should be taken as an indication of our unusual point of view rather than as a sweeping and serious criticism of mathematics teachers. In a recent paper on "The Teaching of Physics" Messrs. Franklin and MacNutt call attention to the fact that almost every definition in physics rightly understood is a physical operation, and in our class work we frequently call this fact to mind by asking the question "How do you define a cow pasture?" the answer being "By building a fence around it." There is scarcely any point in connection with the teaching of physics in regard to which our point of view is not adequately epitomized by this question and answer. Nearly every mathematical operation refers to physical reality in a manner as insistent and as real as the operation of multiplying two dollars per day by one hundred days. and this operation is 100 days of hard labor!

Among the things listed by Francis Bacon as most needful for the advancement of learning is a "New Engine." or a "Help to the Mind" corresponding to "Tools for the Hand." and the most remarkable aspect of present-day physical science is that aspect in which it constitutes a realization of this "New Engine" of Bacon's. We continually force upon the extremely meager data obtained directly through our senses, an interpretation which in its complexity and penetration would seem to be entirely incommensurate with the data themselves, and we exercise over physical things a kind of rational control which greatly transcends the native cunning of the hand. The possibility of this forced interpretation and of this rational control depends upon the use of two complexes: (*a*) *A logical structure*. that is to say, a body of conceptual and mathematical theory which is brought to bear upon the immediate materials of sense. and (*b*) *a mechanical structure*, that is to say. either a careful *arrangement of devices*. such as the devices used in making measurements. or a carefully planned *order of operations*, such as the successive operations of solution. reaction, precipitation. filtration and weighing in chemistry.

The greatest conflict in philosophy in our day centers around the old-fashioned notion that all things are rational in the sense of being seated or seatable in the mind as ideas and capable of formal as opposed to material expression. The pragmatist has the winning side in this conflict. and opposed to him is what William James has called the "tender minded" philosopher, who for a thousand years has exemplified increasingly the hopelessness of the talkative kind of philosophy in our dealings with physical things. In the field of technical education the teacher of physics is the pragmatist, and the typical teacher of mathematics with his predilection for the tender minded philosophy must look out, for his activities are coming to be seriously out of harmony with the only thing that justifies his existence, namely, the handing down to young men of the New Engine of the Sciences.

THE PRECEPTORIAL SYSTEM, AND ELECTRICAL ENGINEERING AT UNION COLLEGE.

BY WALTER L. UPSON,

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THE PRINCETON SYSTEM.

Princeton's greatest contribution to education in recent years is the preceptorial system which was established by President Wilson in 1905. This system superseded the old one of lectures and recitations, still in use in most institutions. In some instances lectures and recitations were continued much on the old plan, with an addition of preceptorial work, while in other instances the bulk of the work became preceptorial. Preceptorial work as actually performed varies considerably in different departments. In the languages and subjects which place emphasis on reading, such as history, economics and philosophy, classes meet twice a week for lectures. They also meet once a week in small groups with the preceptor for the purpose of intimate discussion and report on assigned reading. In other subjects, particularly mathematics, preceptorial work is rather an additional aid and stimulus to weaker students. Preceptors have their appointed hours for attendance in the class-room and there they meet individual students who have been requested to appear because of evident weakness, or who come voluntarily for additional explanations and practice. By these meetings it was sought to bring about a closer intimacy between the student and his work, and between the student and his teacher. The preceptor should become the student's "guide, philosopher and friend" and thus stimulate enthusiasm for scholarship and learning, and devotion to the higher ideals of life, and also he should encourage him to form the habit of reading.

Much importance is attached to the method of the system, not only because it brings about a closer contact of students and teachers, but also because it permits the work to be adjusted to the needs and peculiarities of the individual student. In other words, the preceptorial system is important on account of its flexibility. Nevertheless, it is evident that the merit of the system depends largely on the merit of the preceptors chosen to carry it out, and as this fact was recognized from the first, great pains have always been taken to insure obtaining desirable persons. In practice the plan has been sufficiently successful to warrant its continuance with only slight modifications.

The objections to the system are the enormous expense and comparatively small opportunity for promotion of preceptors, and the difficulty of obtaining satisfactory preceptors.

The Preceptorial Principle as Applied at Union.

At Princeton, technical education was scarcely involved, at least at first, in the new scheme, and if it had been it is doubtful if the engineers would have been called on to play an important rôle in its development. It is safe to say that the preceptorial system has never received much attention from engineering teachers. At the present time, and always, it reflects its academic environment. Efficiency, in the engineering sense as ratio of output to cost, is not considered. Rather, at Princeton, they are willing to pay the price in order to get an output of the highest grade. The plan and conduct of the electrical engineering course at Union College is suggestive of the adaptation of the preceptorial system to engineering education. It might almost be said to be an embodiment of the engineer's idea of the way to carry it out. Yet, in laying out the course at Union, the Princeton system was not at all in mind, and consequently, the Union system is a quite distinct and original attempt to obtain for electrical engineering the ends sought by Princeton for her academic departments.

With a background of technical training in Sweden, and with many years of practical engineering experience in this country, Dr. Ernst J. Berg took with him to Illinois a fresh conception of the way to meet the needs of electrical engineering students. At Illinois, he applied and developed his ideas, and coming back to Union, he brought with him the matured system which is now the basis of the electrical engineering course. In this course it is sought to turn out a product of the highest grade, but to do it with the utmost efficiency. The quality of the product is measured by the engineering knowledge, insight, power of analysis, power of concentration, discriminating sense, judgment, honesty, tolerance and enthusiasm of all those who graduate. It is believed that the course now offered at Union tends to develop all these qualities, but to do it with maximum efficiency.

Efficiency is obtained by the elimination of unnecessary administration requirements, of unnecessary duplication of lectures, of unfamiliarity on the part of one instructor with what another is doing, of unnecessary drilling and "forcible feeding" of students, and by the harmonious interrelation of students and instructors who live and work together every day.

The plan of the purely electrical work is extremely simple. It lays principal stress on a course of "theory" three hours a week, and a course of "laboratory" two afternoons a week, through junior and senior years. There are no other electrical courses given to juniors. Seniors spend three hours per week for two terms carrying out practical problems on "design," and one period of two hours per week through the year in a course called "Seminar" which includes presentation of papers and discussions by the students themselves. Some seniors also present theses, while others repeat, in part, the junior theory.

The total schedule of both juniors and seniors is given as 17 hours per week. Approximately 70 per cent. of this time is given to engineering subjects of which 75 to 80 per cent. are electrical.

Details of the Courses.

The "theory" courses are conducted as follows: Dr. Berg gives the advance lectures, averaging slightly less than one a week each to juniors and seniors. The "theory" periods between lectures are given over to class work, recitations, quizzes and tests. For the class work the students are divided into sections averaging eleven men, each section under the direction of one of the instructors. This enables work to be done at the board, or in any manner that the situation calls for at the time. The principal problems are assigned at the lectures, and they are made to illustrate the subject under discussion. As no regular text-books are used, it is necessary for the student to avail himself of what is offered in class in order to be able to work the problems. He must draw heavily on his notes and his class-room practice, and, further than this on his instructors, for help. But he must do the work.

To give a specific illustration of the operation of the course we may take, for instance, the study of the short-circuit of alternators. This subject was reached as a natural development of the study of alternators, about the middle of February, and occupied the attention of the seniors for about two weeks. In the first lecture the fundamental equations of the transient armature current were derived, and the general conditions established, and a problem was assigned based on known experimental data. The problem called for the plotting of armature current from the instant of short-circuit. As the result would vary, depending upon the instant at which the short-circuit occurred, the class was divided into groups, each group being assigned a different time of closing the switch. The physical idea of the transient phenomena was not easily grasped at this point, although the mathematics were entirely familiar, and it took several class hours of effort before it was felt to be time for another lecture. The second lecture was given nine days after the first, and consisted of a further development of the subject, in the establishment of the equations of other variables, that is, of the field voltage and current, armature reaction, both for three-phase and single-phase short-circuit, and the power for single-phase and three-phase. This lecture was, in reality, not concluded until a week later. In the meantime the work of calculating and plotting was carried on, while the class work of assimilation continued on intermediate days. During this time the interest in short-circuits became so great that the class wanted to study them first-hand with the oscillograph, and consequently this became the order of the laboratory work. Incidently some peculiarities were discovered in the behavior of certain laboratory alternators, and of course these added to the interest.

At the same time in design, the alternator was being studied from another point of view, so that during the whole period the class was being steeped in this subject.

This is just one example of the operation of the course. The class procedure on other occasions may be quite different, and may involve a discussion of the previous lecture, or may require a supplementary lecture by the instructors. Each instructor, while following the same general scheme, will naturally be independent in his way of carrying it out. All instructors attend the advance lectures of Dr. Berg, or will have attended them in a previous year. These lectures form the basis and set the pace for the entire electrical work. The important feature of it is that the pace is adjustable, for just as soon as the students are ready for more, they get it.

At the same time work in the laboratory is running along parallel to the lectures. Frequently interesting questions come up in a lecture, and these may be at once investigated as a regular part of the laboratory work. The same opportunity for flexibility is found in the laboratory as in the theory. If students get hold of an interesting question they are encouraged to continue it until they have finished all that can readily be done. There is always an instructor freshly acquainted with the subject to suggest new lines of investigation. Furthermore, there are always two instructors present at every laboratory period, whose services are always available but not obtruded upon the students.

The interrelation of theory and laboratory is made even more complete by short supplementary lectures given at the beginning of laboratory periods, intended to apply the theory to laboratory methods and vice-versa.

So much applies to both juniors and seniors. The latter concentrate their efforts even more closely on the subject in hand. While they are studying the induction motor in theory and laboratory, they are also working on induction motor design, and as a fitting conclusion of the subject, a debate is held in seminar on the subject "Resolved: that in general, squirrel cage induction motors are inferior to other types." It is easy to see that with such an attack on any subject, every man in the class feels himself able to talk intelligently and definitely upon it. Thus, the student has had the way constantly pointed out to him, but he has not been carried along. He has progressed by his own effort, he feels personally acquainted with induction motors and he likes them.

Faculty and Students.

The housing of the department is another very important element in the scheme. While the laboratory building was not designed to be used as at present, yet it has been possible, by careful planning, so to alter the interior as to provide two large recitation rooms and four offices, also space for students to work at large tables, all in addition to the regular laboratory. All engineering classes, both junior and senior, are held in the building. The actual time spent by students in the building will average over three and one half hours per day, per student. When it is considered that the faculty is practically always present in the building during the working hours of the day, and that their offices are always open, and accessible, some idea will be obtained of the relations between faculty and students. One junior, who was rather lazy, said that he would do the work all right if the instructors would just keep after him. But that is not a part of the system. There is no compulsion about the work except a moral compulsion, which comes to a student from his own knowledge that he must come up to the standard of the department or be dropped. This junior was told that he would be helped as much as possible but would not be driven. The natural result was that since then he has kept up by his own effort, and has learned a good lesson in self-reliance.

The work of the faculty is quite different in character from what it was under the old system. Class work is very light; it amounts to but five or six hours per week per instructor. From its nature it demands very little effort on his part. At the same time, much more effort is put into the work of going over the problems so that the student shall have the benefit of personal supervision of his work and may profit by having his mistakes pointed out to him. But, even this does not take a great amount of time, for the student has been taught and is required to do his work in an orderly manner.

In addition to prescribed teaching, every instructor is expected to be engaged in some scientific or engineering investigation. Since nearly the whole time of the faculty is spent in the laboratory under favorable working conditions, research becomes a natural occupation. Research, in so far as it involves experimental work, is conducted right in the laboratory where the students are also at work. The idea is to bring into touch all classes of work and workers, so that those just beginning may catch the spirit of those who have had a great deal of experience. Thus instructors, graduate students, seniors and juniors are all working more or less together. As more room is required, the work is simply spread out, but not to any great extent subdivided into departments. Incidentally, this has an advantage in the economical use of apparatus.

Relation of the Electrical Department to the College.

It would not be right to conclude without mentioning certain elements which belong to the college as a whole, but which have a decided influence in the carrying out of the present plan at Union. Most important is the fact that the honor system in examinations is in force, and through its working there is no trouble in securing trustworthy results. Again, Union College is small enough so that students of all departments are well mixed and partake of one another's interests, and large enough so that an atmosphere favorable to any particular line of work may readily be maintained.

As evidence of the success of the system many incidents might be related which would all show a very unusual degree of enthusiasm on the part of both students and faculty. Of twenty-three seniors, it may be said that six expect to return for graduate work in full residence. An especially gratifying result is that the enthusiasm is not confined to a particular group of students, as for instance, the brightest ones, but every man feels with satisfaction that he has accomplished something which has been worth while, and that it has been by his own hard work.

Conclusion.

Princeton has devoted a large part of her resources to the maintenance of a system designed to bring students into more intimate relationship with learning and culture. The keynotes of this system are close association of students with preceptors, and flexibility of method. This close association calls for a great increase in the faculty, and flexibility is made possible by the increase. Flexibility is the most vital element in the method. Without it, close association would be intolerable. It is inseparably joined with the interest and progress of the individual student.

The weakness of the old method is in its inflexibility. It is a social order applied, without means of adjustment, to the individual. The rate of progress is the same for all, and fits only a few. Union College has accomplished flexibility in the electrical engineering department, not by an increase in faculty, but by a simplification and rationalization of its methods. Flexibility is the result of the method. To bring about this change involved a recognition, first, of the futility of multiplication of courses; second, of the necessity and sufficiency of a sure understanding of the fundamentals on the part of each student, and third, of the essential elements of successful teaching. From this standpoint it was easy to arrange the present course. Electrical engineering may be peculiarly adapted to it in that, while there are many branches to the subject, they all radiate from the same central stalk.

In applying the principles of the system to another subject, or to another institution, considerable variation in details might naturally result.

At Union, account was taken of local conditions, and, fortunately, these all seemed to be favorable. Whether generally applicable or not, the results already achieved at Union have not only amply justified the course, but they have seemed to justify, as well, the preparation of this paper.

TEACHING ENGINEERING STUDENTS HOW TO STUDY.

BY GEO. L. SULLIVAN,

Professor of Mechanical Engineering, University of Santa Clara.

We expect engineering students to study, in fact we require them, under penalty of failure, to study a great deal. We seem to take it for granted that students have some instinct which directs them in their study and that they know intuitively how to study properly. While this is the main requirement of students we give it the least attention. If we tell a student to determine the ultimate strength of a specimen of steel we give him detailed directions how he shall go about it and we check his method very closely but we tell him to study the laws of equilibrium and then pay not the slightest attention to the manner of his studying. He may learn to repeat the laws parrot like, although we usually do not even tell him the best way to do that. He may learn the laws and connect them only with the examples given, as is illustrated by the fact that most students think of acceleration as a phenomenon connected with falling bodies only. Or he may secure a definite view of the object of the whole subject, may get its different aspects organized in his mind and may check, connect and associate the laws with as many familiar examples as possible.

Believing that there was a real need for instruction in "How to Study" the writer advised the addition of such a course to the freshman schedule and took charge of the class. In outlining the course the following effects were decided on as the results which was hoped to be accomplished by the course.

I. Teach the students how to study properly.

II. Cause them to form the habit of reading technical magazines and books.

III. Give them a general knowledge of the fields covered by different branches of engineering.

In order to accomplish these results the following outline was developed:

First. Ask the students to outline their methods of studying.

Second. Assign some question, which the students are more or less familiar with and interested in, to be studied without any suggestions of the method to be followed.

Third. Read the studies that have been made by the students to the class and ask for criticism. If the subject has been well chosen and the criticism wisely directed, the fact will be brought out that the question was really not studied at all in some cases and very poorly in most cases. This should bring home to the student the fact that he does not know how to study properly.

Fourth. Point out the main error in each paper. Some will not have recognized the question at all, most will start with some conclusion and simply defend that conclusion, many will fail to use much of the available data, etc.

Fifth. Develop a logical method of study and have the students apply this method to as many questions as possible. Show how it can be applied and have them apply it to their other lessons, to simple problems in engineering and to every-day problems of life.

Sixth. By assigning proper questions and giving references to technical magazines and books cause the students to become familiar with the technical journals and the card catalogue of the library. Choose questions in the study of which the students will get a glimpse of the big questions and the broad divisions of engineering and in the discussions bring out the things that make engineering worth while and that furnish inspiration to the students.

In the writer's class most of the students answered the question "How do you study?" by saying that they memorized the formulas and worked the asigned problems or simply that they read the lesson over carefully and tried to understand it. Usually there was no idea of studying with the idea of learning the relation of the parts studied to the whole subject or getting a broad understanding of the subject or of checking the author's statements or of applying the rules or formulas to any but the applications given in the text.

The first subject assigned was "Would it be practical to depend on electricity for heating and cooking if you were building a new house here in Santa Clara?" References were given to a number of articles in the technical press. Practically all of the students declared that it would be practical to so use electricity and then gave one or two of the arguments from the magazine. Some launched into a criticism of the public service corporations and only one man in the class compared the cost of wood and gas in his own home with the reported cost of electricity and even he did not take into account the difference in rates. After discussing the papers the class agreed that they had not studied the question.

After the students realized that they did not know how to study properly we developed a method of study and applied it. The first step in this development was to determine what study is and the object of studying. The fact was brought out that there are two kinds of study, pure memory work, which is not study in its broad sense, and mental work which involves the selection of material and the drawing of conclusions. Things which are constantly used should be memorized to save time and the best way to memorize a thing is to associate it with as many things as possible in as many ways as possible. Write it down and speak it aloud so as to receive sensations from it through the hand, eye, mouth and ear.

Study in the broader sense, which includes memory work, is applied by everyone to the problems of life and is the kind of study that is most valuable to a student. The first step in this kind of studying is to determine the object of the study. We took up several textbooks and analyzed several chapters in each to determine if possible just why the author treated the subject as he did. For instance, we noted that Smith, in his "Descriptive Geometry," first treated the representation of points, then of lines, then of planes, etc., and the reasons for this development were brought out. The students were thus led to a realization of the problem confronting an author in conveying his ideas to their minds and they saw more clearly what he was trying to do and were enabled to coöperate with him to better advantage. In the same way other elements of proper study such as an open attitude of mind, schedule of study time, absence of distractions, collecting data, arranging data, checking data, drawing conclusions, memorizing and application were taken up and applied.

Familiarity with the technical press was given by assigning such problems as "What are the opportunities for the technically trained man in the automobile industry." The first step in this study was a determination of the object of the study and obviously the object of this study was to enable each man to answer the question "Shall I enter the automobile industry?" Such questions as this enabled us to accomplish the three primary results noted above.

Some students are glad to know there is a proper method of studying and conscientiously try to follow it with good results; others, knowing the better way, make no effort to follow it but are content to follow the slipshod methods they are in the habit of using. In general, students will learn whatever is required of them and if the instructor lays stress on memorizing rules and formulas instead of on understanding the subject, that is what the student will do. On the other hand, if the instructor will explain the object of the next lesson and what the author is trying to accomplish in it, the students will be able to apply the elements of proper study to much better advantage.

Discussion.

Professor Wm. S. Aldrich (by letter): Is "teaching engineers how to study" a different proposition from teaching others how to study, or more difficult? Is there an educational psychology for engineers, a pedagogics especially adapted to their needs, as we have come to think of the calculus for engineers, and of English for engineers? Translate a possible threefold object of education into terms of our own craft. It might read thus: A training for vocational efficiency, for social efficiency, and for proficiency in some avocation. Amid intricate interweavings of the warp and woof, we soon recognize in the design the threefold significance of the whole educational process; physical, intellectual, spiritual.

To what extent has the student control or responsibility, subjectively, in the way of stimulus or inhibition? To what extent likewise, but objectively, has the teacher this control and responsibility? We discern a factor now to be reckoned with in the realm of the highest functioning of the mind, in such an expression as "the will to believe." Of immemorial usage, and with particular reference to physical achievement, is the adage, "where there's a will there's a way." Let us bring these two concepts together,—bring them into the realm of the purely intellectual which we may grant the existence of, in lieu of more extended discussion of the unity or diversity of the functions of the brain. Let us say, "the will to learn." Why not, "the will to study?" There is no distinction here, with a difference of the most vital importance to us, as engineering educators.

Engineering education is at once an education in a science, in an art, and in a culture. The engineering student must not only study, as the veriest disciple of "art for art's sake," a true defendant of culture; and as a devotee of science, a staunch proponent of knowledge. He must become proficient in the rudiments of an art, that he may enter its domain and advance the practice thereof; namely, the utilization of the forces and resources of nature for the comfort and convenience of man. Hence, we may say, "the will to learn," rather than "the will to study," or even "the will to know."

What will minister to the development of will power, as a kind of psychic motive force, permeating, animating, energizing; pushing, pulling, driving by stimuli and inhibitions;

commander-in-chief of all the forces and resources, offensive and defensive now at its call through countless ages of its evolution. What, in short, will summon to its proper functioning and possibilities, man's heritage of an indomitable personal will? The psychologist answers, "interest," the economist, "profits," the sociologist, "service," the moralist "duty," the egoist, "ambition." The philosopher, whom we may suppose to be still aware of a certain Greek joy in life resulting from the harmonious development of all functions, will answer "happiness." To the student, the graduate, the practicing engineer, one or more of these subtle influences from within or without, stimulate him, in the words of Thomson, "to learn the next lesson in will development, and win Carlyle's great equipment for life, the ability to take trouble." We can make our own brains, so far as special mental functions or aptitudes are concerned, if only we have wills strong enough to take the trouble. Each such self-created brain center requires great labor to make it, because nothing but prolonged exertion of the personal will can fashion anything of the kind. It cannot be done by proxy. The student must do it himself. A person, therefore, acquires new brain capacities by acquiring new anatomical bases for them in the form both of brain cells, which he has trained, and of actively working brain fibers, which he has himself virtually created. This is the view of the physiological psychologist. Perhaps it is only an hypothesis. But what of those who have, pragmatically, sought to establish it by seeing if it worked? We quote again from Thomson: "To keep on steadily doing what the mind recognizes as the right thing, such a store of will power is needed that but few are found who have it. And those who have this will power, strengthened and developed by constant exercise, as many lives has shown, demonstrate the dominance of a personal will as an active agent in fashioning brain matter."

May the object of education change? A half century ago it related almost solely to human conduct. It was phrased by Spencer "to make man a self-governing creature." May we not notch up, now, for the next run; and say, at least, as engineering educators, that the object of our work is to make man an efficient, self-evolving creature, with a constant tendency to progress, actuated through a brain which he is daily fashioning anew to higher functioning, under the dominance of a personal will.

Appended is a brief syllabus, also a short bibliography. The one has no particular relation to the other. The books listed are not the only ones, perhaps not the best to be had. They will be found helpful and stimulating. The outline of reading and individual study might comprise about thirty semester hours. We do not say "take the next ten pages, and turn in a written report at 9:15 tomorrow morning, under penalty of suspension." We do say "Let us try to ascertain how, when, where, and why, we, as teachers of youth, continue to educate ourselves, to train our faculties to become obedient servants of the human will." Then let us give our students, as the 'prentice hands, the benefit of our own experience. Perhaps we may show them that the case is not hopeless,—show them a third important idea, derived from the Greek, as Dr. Horne has coined it, "eunoia" (good will power). It is that, surely, over which we have increasing control. Beyond "eugenics" and "euthenics,"—good heredity and good environment,—let us nurture another gift, "eunoia," good will power.

SYLLABUS.

1. History of education: (*a*) general survey, (*b*) in the United States.
2. Educational psychology: (*a*) the individual, (*b*) the group.
3. Principles of education.
4. Method and its principles.
5. Experimental education.
6. Practice teaching.
7. Special topics: vocational guidance, the fine and the industrial arts; the college and the community.

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Hinsdale: Art of Study.
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Huey: Psychology and Pedagogy of Reading.
McMurray: How to Study and Teaching how to Study.
Spencer: Education.
Thompson: Brain and Personality.
Todd: The Student's Manual.

GIVING INSTRUCTION IN METHODS OF STUDY.

BY W. H. KENERSON,

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The writer agreed to discuss this subject when filled with preëxamination confidence. Now that the results of his own efforts are before him in the form of final examination papers he, as usual at this time of year, is chastened in spirit and unwilling to advocate as infallible his own methods of giving instruction in methods of study.

The paper by Professor Geo. L. Sullivan in the May BULLETIN* records an interesting experiment. At Brown University we have attacked the problem in a different way. Instead of giving a specific course dealing with the subject of study, we are endeavoring in connection with some of the regular courses to teach the student to devise and practice the best methods of study applicable to each particular course. This is done because we believe that different subjects taught by different men require radically different treatment.

It is very doubtful if any standardized method of teaching how to study can be evolved. The majority of us even find difficulty in the much simpler problem of fixing proper tasks for the students. Our judgment in such matters changes radically as our years of service increase. It will probably be some time before a slide rule is devised which will enable an instructor to accurately determine the number of allowable "cuts" together with the rate of feed, or pressure, to be brought to bear to drill a given student in a particular subject.

That students do not know how to study when they reach college is not surprising. That is one of the principal things that they come to college to acquire. It is easy to assume that the burden should rest with the secondary school, but as a matter of fact study of the type desired in college involves besides memory, logical reasoning, and the collection and arranging of data, such elements as the weighing and balancing of values, and the drawing of conclusions, which essentials come only gradually with age and experience.

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* This paper formed part of the program of the Princeton meeting. See p. 163.

Young men are too immature to have acquired the whole art of study before coming to college. In our enthusiasm for, and anxiety to impart, the subject matter of our courses we may forget this limitation and the fact that, after all, the important thing to the student is the manner in which he studies a subject.

To get at the root of the difficulty we are endeavoring in some of the courses to have the greater part of the study done under the direct supervision of, and with the assistance of, the instructor. This may seem to some like lower-school methods but experience has shown that the results justify the means.

In order to save time students are asked to collect certain facts and to be prepared to answer certain very definite questions which may have a bearing on the subject to be studied, but the real study in the course is done while a small group, including one or more instructors, is seated around a table for informal discussion.

The time so spent is not a recitation period, the very name of which, suggestive of mere memorizing, is distasteful to the writer. It is really a thinking or study period taking the place of the usual recitation period but proving far more effective both as a means of mental training and as a time saver.

No "marks" are assigned for work done at these periods as experience has shown that when the thought of "marks" is introduced the attitude of the student toward the work is entirely changed. "Marks" are assigned on the basis of what the man does as a result of the study periods and this is determined by examinations, reports, a syllabus or a set of notes.

The student is encouraged to improve on his first attempt and if, after further study or conference with the instructor, he desires to rewrite, amend, or otherwise improve his first report he may do so and only the final result of his efforts is considered in fixing his grade in the course. Some men progress much faster than others, but the emphasis is laid where it properly belongs, namely, on results.

By this plan the student realizes that he meets with his fellows and an instructor not to be tested as to what he knows but to find out by observation how others, including one who is presumably trained to study, attacks a subject. As no penalty is attached to preliminary ignorance, and in fact ignorance at the beginning is assumed, the students freely express themselves, giving the instructor opportunity to get a good idea of their methods of thought and capacity for doing work. Reference books from the library, catalogs, etc., are placed before the students and their use demonstrated.

A similar idea is carried out in connection with courses that involve the solution of problems, as in mechanics and thermodynamics. Such problems are solved in the presence of an instructor who at all times stands ready to tell a student if he is on the right track and to correct his work, but not to tell him how to do it. Here again the final, rather than the first result, is the one which determines the student's mark.

The time devoted to such work has been cut to less than one half that which was required when the work was done independently outside class and with far better results, as is evidenced by the final examinations.

There is, of course, nothing novel in the plans outlined above. It may, perhaps, be interesting, however, to some to know that the results obtained by this method have been very gratifying and that students enjoy the freedom of it. They assure us that they profit by it. Such a method implies, of course, a sufficient number of instructors of the right type to teach small groups. After all, the solution probably depends on the proper choice of instructors. Our colleges must engage men who are not only scholars, but men who are teachers and possessed of such personality that they can inspire the confidence and respect of the students.

The purpose of this paper is not to attempt a solution of the question involved but merely to serve as a catalytic agent which, without contributing anything from its own substance, may induce a combination of ideas from the experience of those present which will result in really valuable suggestions regarding this most important subject.

COORDINATION IN ENGINEERING INSTRUCTION.

BY A. B. McDANIEL,

Assistant Professor of Civil Engineering, the University of Illinois.

Although the writer is still a novice in the field of engineering instruction, having just completed his eighth consecutive year of teaching, certain features of this department of the pedagogical field have aroused his especial interest. There are two general divisions of the subject which will be discussed; first, the correlation of subjects taught, and second, coordination in the departmental organization.

CORRELATION OF SUBJECTS.

Coming directly from several years of intensive practical experience and entering upon the duties of a teacher in a large technical school, the writer was soon impressed by the lack of coördination and correlation between the different departments and the subjects taught. The curriculum seemed like a bill of fare of a quick-lunch restaurant, where the strenuous patron bolts a series of ill-assorted dishes. Perhaps this accounts for the large amount of mental malnutrition which is prevalent among our students. The amount of unrelated and unassimilated knowledge which the average technical student possesses upon his graduation is astonishing. This knowledge is generally in the form of abstract facts and ideas which the young, inexperienced graduate is unable to apply to practical purposes. He has knowledge but lacks the power of application. The late C. R. Crane, of Chicago, made a vigorous and to some extent a justifiable attack upon the technical schools of this country. One of his chief contentions was the impracticableness of the training which the technical or engineering student received. Recently J. J. Hill made the statement that collegiate instruction is indefinite and inaccurate. The speaker has had the supervision of a large number of young technical graduates during the past ten years in practical engineering work. He well remembers the case of a graduate of the civil engineering department of one of the largest and best known state universities, who could tell him about the convergency of meridians and yet could not correctly check up a traverse for a proposed drainage canal twenty miles in length. This is but one of a large number of observed instances all of which point out the folly of teaching a subject in a purely theoretical manner. All subjects should be so taught that the knowledge gained may be intelligently applied in practice.

The lack of coördination is especially noticeable in the studies of the freshman and sophomore years when there are a large number of non-professional and cultural subjects taught. The latter are generally taught by academic teachers who have had little or no technical training and experience. In recent years, some very valuable and instructive papers on instruction in English for engineering students have been presented before this society. Still more recently the subject of mathematics has been taken up and discussed. An interesting and valuable syllabus is one of the concrete results of this discussion. A fair question is; ‘ Has this syllabus been adopted into any schools and if so have any efficient results been achieved?’ Let us consider further this subject of engineering mathematics and for this purpose the writer will present his ideas based on a recent experience.

During the first part of the freshman year, the student is taught plane trigonometry. This is followed in the second half of the freshman year or in the early part of the sophomore year by a course in plane surveying, and in the junior year by a course in railroad engineering. The trigonometry is often taught by a teacher who has very little knowledge of engineering and furthermore does not take the trouble to inform himself concerning the courses in which his students must soon apply their knowledge of mathematics. The academic teacher uses one of a number of well-known text-books and assigns in the usual routine way a series of lessons and problems from which the student is supposed to derive at least a working knowledge of the subject. Generally, the speaker has found the student equipped with a vague idea of the trigonometric functions. Beyond the fact that they are certain abstract fractional forms, they mean very little to him. He does not readily see their significance in the solution of problems on paper, and in the field. Especially is he deficient in the ability to visualize these fundamental trigonometric concepts and quickly grasp their applicability. The reason for this is clear. *The subject is taught in an abstract way and not in correlation with the dependent branches of engineering.* Some schools, notably the college of engineering of the University of Minnesota, have endeavored to solve the problem by employing teachers with engineering training for the courses in mathematics. This method has proved to be quite satisfactory and efficient. Unquestionably such teachers vivify the subject, and present it in a concrete manner, having always in mind the future applications of the principles which they are drilling into the minds of the students.

During the writer's first year in teaching surveying and railroad geometry in a department of civil engineering in a western state university, his attention was often drawn to the inadequate preparation of the students in mathematics. However, the department of mathematics there was considered strong and efficient. It was often found necessary in the classes in surveying to devote several whole exercises to instruction in mathematics. The second year brought a change in the head of the department of mathematics and the speaker took occasion to hold several long conferences with the new teacher, who expressed a sincere desire to coöperate in securing greater correlation of subjects. The instructors of the department did coöperate in this work by requiring the students to work out a large number of practical problems, and required the use of the chain, compass and transit for the solution of simple geometric and trigonometric problems in the field. The increase of actual working knowledge of the average student was noteworthy and resulted in a greater enthusiasm and capacity for the engineering subjects.

The course in plane surveying was thrown open to students from other colleges and generally the writer would have several non-technical students in each class. These students had very inadequate and limited previous instruction in mathematics, especially trigonometry, and it was deemed advisable to give considerable drill in those principles of geometry or trigonometry which applied to the lesson on hand. The students were first made familiar with the construction and use of the surveying instruments. Then they went into the field and laid out simple geometric figures and by the use of the tape, compass and transit, they soon became familiar with various methods of measuring lines and areas. The trigonometric functions became comprehensible relationships and useful tools. After a thorough mastery of the elementary principles, the students were given more complex problems in land and railroad surveying. It was both surprising and gratifying ing to note the facility with which the average student acquired a practical working knowledge of mathematics under this coördinate system of teaching. The non-technical students attained average, and in many cases high rank in the courses. The students seemed to develop an unusual amount of self-reliance and self-confidence and were eager to put in a large amount of extra time in solving the more difficult field problems.

The subject of calculus as generally taught is a waste of time. The average student, two years after graduation, cannot do a simple integration. Several years ago, while the speaker was employed in the office of well-known consulting structural engineers, it became necessary to compute distances along elliptical hip and valley girders of a steel hemispherical roof. Of thirty technical graduates in the office, only three had any definite conception of how to do this. Calculus should be taught by the graphical method and especial emphasis laid upon the solution of problems which often arise in practical work.

Least squares and differential equations mean very little to the average student, when taught in the ordinary routine, academic way. But let the fundamental principles of these subjects be applied to the solution of problems in geodetic surveying, precision of measurements and the design of electrical machinery and they become live and vital to him.

The rational method of procedure in teaching is to give a student a problem and to suggest to him, generally by questions, the way to attack it and the tools to use. After he has solved a few problems in this way he will understand and appreciate the underlying principles and the philosophy of the subject. Fundamenal truths learned in this manner will be remembered long after abstract statements of fact are forgotten.

Many will doubtless claim that the foregoing suggestions will tend toward an undesirable commercialization of technical education and that the mental training and cultural development to be derived from the study of pure mathematics must not be lightly disregarded. The writer does not underestimate mental training *per se,* but efficient technical instruction demands something more than the mere exercise of the brain and storing up of abstract knowledge. The *sine qua non* of efficient engineering instruction is the development of mental power in the students. They should be equipped with sufficient energy and ability to apply the fundamental principles which they learn in the class-room to the solution of practical problems. This equipment will result only from the simultaneous acquisition of abstract facts and a knowledge of their uses.

To recapitulate, it is the writer's belief from his study and experience, that elementary mathematics (and perhaps the advanced branches) can be taught to the engineering student more efficiently and economically, in coördination with engineering subjects. The teaching should always be done by an engineer having a thorough training in mathematics and a wide experience in the field of engineering.

COÖRDINATION OF DEPARTMENT ORGANIZATION.

In the second part of this paper, coördination in engineering instruction from the viewpoint of departmental organization will be discussed.

Let us consider a department of civil engineering of a typical college of engineering in a large State university. The department is composed of several sub-departments such as, railway engineering, structural engineering, highway engineering, hydraulic engineering, etc. Each sub-department has a head and several subordinate teachers, and all are directly subject to the authority of the head of the department. All this sounds like an efficient, business-like organization in which would be found the closest coördination, and harmony of coöperative association. But unfortunately such generally is not the case.

The head of the department is its chief executive, and represents the department in the higher administrative councils of the university. Generally the larger part of his time is taken up with the minutiæ of administrative affairs. He rarely, if ever, visits a class and is generally uninformed in regard to the teaching ability of his instructors. Occasionally the head professor will base his opinion of his subordinates upon mere hearsay, such as student criticism.

Department meetings are held spasmodically or at infrequent intervals. Such occasions are often formal ratification meetings of the policies and acts of the department head. There is ordinarily felt such a feeling of repression and constraint especially among the younger members of the staff, that freedom of thought and effective speech is impossible. Hours of valuable time are often consumed in profitless discussion about trivialities. Dignified professors will ponder and quibble over technicalities to an extent that would shame a lawyer's association. Matters of this character could and should be settled by an intelligent clerk under the supervision of the department head.

Primarily the organization centers in the arbitrary authority of the head professor. The subordinate teachers act as a number of independent units, each one supreme in his own sphere of activities and ignorant of the work and ideals of his associates in coördinate lines of work. The results are inefficient teaching, inadequate preparation of the student for subsequent courses, and duplication of work. Such a condition of affairs would never be tolerated in an efficient business organization.

The writer has suggested some of the elements which lead to weak and loose departmental organizations. During the time that he was professor of civil engineering in a western State university, he also was the directing head of an engineering company. The thought had often occurred to him that some of the methods used in such a company could be successfully applied to the organization of an engineering department of a technical school or college of engineering. For example, in our engineering company, every employee handed in a complete report at the end of each day's work. Why should not every assistant, instructor and professor hand in weekly reports to the head of their department? Such reports should state the hours of class-room, laboratory, and field work; the character and extent of the ground covered; notes on the work of students; recommendations concerning changes in courses; methods of teaching; etc. At the end of each week there should be a meeting of the department, or sub-department heads to consider matters of administration. A careful consideration of these weekly reports would afford the administrative officers and especially the head of the department, a comprehensive idea of the work done in the department during the preceding week. The reports would also indicate the amount of time which each instructor was giving to the various phases of his work, the results accomplished, the industry and initiative shown, etc. Such information is necessary in the consideration of the promotion of various members of the staff.

As a chief engineer of a large engineering company or project occasionally makes personal inspection trips to the various parts of the work going on under his direction, so the department chief should make inspection trips to the various classes held in recitation room, laboratory and field. This is rarely done, yet the speaker is unable to understand how a professor in charge can have an accurate conception of the character and scope of work going on in his department without such inspection. Further, the occasional visiting of various classes by the instructors of the department would inform them as to the work which other members of the staff were doing and how they were doing it.

The accompanying diagram on the sheet before you is a suggestion as to the organization of a department of civil engineering. It should be noted that some branches, such as hydraulic engineering, are in some schools under another depart-

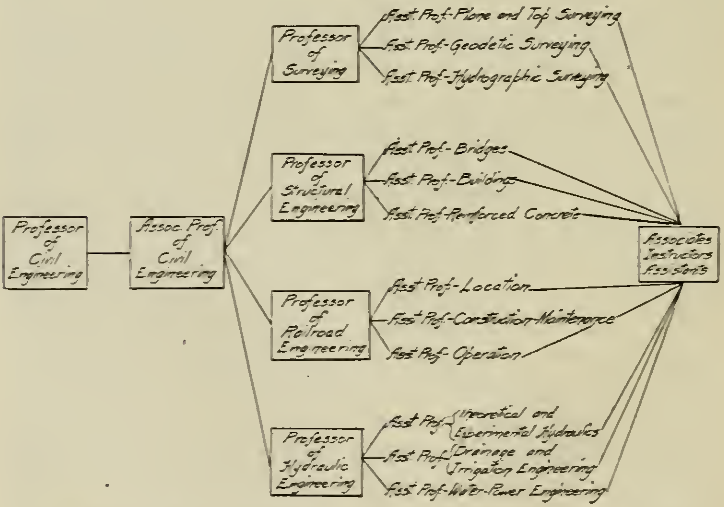
Professor of Civil Engineering
Assoc. Prof. of Civil Engineering
Professor of Surveying
Asst. Prof.-Plane and Top Surveying
Asst. Prof.-Geodetic Surveying
Asst. Prof.-Hydrographic Surveying
Professor of Structural Engineering
Asst. Prof.-Bridges
Asst. Prof.-Buildings
Asst. Prof.-Reinforced Concrete
Professor of Railroad Engineering
Asst Prof.-Location
Asst Prof.-Construction-Maintenance
Asst Prof.-Operation
Professor of Hydraulic Engineering
Asst Prof.-Theoretical and Experimental Hydraulics
Asst Prof.-Drainage and Irrigation Engineering
Asst Prof.-Water-Power Engineering
Associates Instructors Assistants

Diagram of Proposed Organization of a Department of Civil Engineering ment, such as mechanics or mechanical engineering. The writer has not tried to include every branch of civil engineering, but simply a few of the more important to illustrate the schemes of the proposed organization which will be now outlined.

The head of the department is the chief executive and has general authority and supervision over the department. His position corresponds to that of chief engineer of an efficient organization.

The associate professor corresponds to the position of principal or chief assistant engineer of an engineering organization. His duties are to have direct charge of the active work of the department such as keeping in active touch with the heads of the sub-departments, visiting classes, inspection and maintenance of equipment, apparatus, supplies, etc. He is directly responsible to the head of the department for detailed and complete information at stated intervals concerning any phase of the departmental activities. Neither the professor or associate professor should have a large amount of routine teaching to do. The associate professor becomes acting head of the department during the absence of the head.

Each department has its head, or professor, and assistants such as assistant professors, associates, instructors and assistants. Each professor is responsible for the efficient and economical operation of his sub-department and his position may be said to correspond to that of resident or division engineer of an engineering organization. Each sub-department has its regular weekly meetings which all members are required to attend. Each member presents a weekly report filled out on standard (filing-card-size) form. The report states: subjects and number of hours taught in class-room, laboratory, and field; character and extent of ground covered; recommendations and suggestions as to presentation of courses; requests for equipment, supplies, etc. The reports and matters of sub-departmental interests are discussed.

Bi-weekly department meetings are held and attended by the head, associate professor and the head professors of the sub-departments. At these meetings the sub-heads present reports covering the work done in their departments during the previous two weeks. Individual reports of the instructors may also be taken up and discussed. Matters of importance effecting the administration and operation of the whole department will be considered at these meetings.

In the college of engineering will be the departments of civil, mechanical, electrical, mining, chemical, sanitary, and other branches of engineering. Each department will be in charge of a professor and an associate professor who will all be under the authority of a dean and an assistant dean. The former is in responsible charge of the administration of the college. The assistant dean is in direct charge of the administrative details of the college and keeps in close personal touch with all the departments.

Monthly meetings of the college assembly are attended by the dean, assistant dean, heads and associate heads of all departments and of the allied departments such as mathematics, physics, chemistry, etc. At these meetings each department head submits a report and matters of general college interest are dealt with.

As a part of the college organization, there should be a number of committees, working under the assembly, in consulting and advisory capacities. Every member of the staff should be a member of some one of these committees and appointed by the assembly, after a consideration of the written preferences of all the members. These committees shall be on student credits, athletics, college extension work, etc. The activities of these committees should largely shape the policies of the college and all its departments. Thus every member of the staff would feel a personal interest in the welfare and progress of the college. There would be an inducement for the cultivation and exercise of real intelligence and high ideals and the routine of class-room work would be coördinated with the administrative functions which govern it.

The above is a merely suggestive outline for the organization of a department and the coördination of the various departments of a college of engineering. Its purpose is to secure higher efficiency, better coördination, and more real democracy than are now generally existent in such institutions. The college, if it fulfills its complete function, should primarily educate its students to become efficient, broad and high-minded engineers and citizens. This requires that the whole staff and especially the higher administrative officers shall be men of vision, enthusiastic in their work, daily inspirers of high ideals of character and ability in their students and leaders in their various professions.

Another function of the college is to contribute a generous share to the scientific knowledge and understanding of the profession of engineering. To this end, each department and sub-department should have a research man whose whole time and attention shall be given to the investigation of original problems. The members of each department should coöperate with their research man in the suggestion and solution of problems in which they are interested. However, the research man should not teach and the other members of the staff should give their main thought and attention to the instructional side.

A third and highly important function which the college should perform is that of public service. This has taken the form of university extension work in several of the well-known state universities. A college of engineering of a state university should be of real service to the state in the development of its resources and the widespread promulgation of scientific information among the people. The staff of the college should be represented on the engineering and public service commissions and departments of the state. An active publicity bureau should supply the press and literature of the state with information concerning the college activities and especially with articles of practical scientific interest to the people. Bulletins describing the results of original investigations should be issued from time to time, primarily for the enlightenment of the people and not as a method of educational advertisement.

DISCUSSION.

Dean G. C. Anthony: Professor McDaniel has set forth several heresies which demand attention. This question is important especially in that it relates to the coöperation between the members of the different departments, and the knowledge which the members of the department should have of each other's work, and to the understanding that the head of the department should have of the work of all.

Professor W. J. Risley: The teachers of engineering and of mathematics appear to be concerned largely with the coordination of mathematics and the engineering studies. The coördination of other subjects also is important. The University of Cincinnati now expects its professors to formulate syllabi of their courses for the purpose of coördinating them. That scheme brings together the various engineering courses in a way not otherwise possible. The members of the faculty work well together under this plan.

Professor H. H. Carroll: If the head of a department has part of the freshman work he can better arrange a general outline of the work that is to follow. One or more freshman courses could then be built up to prepare the students for practical work, so that those students who leave for causes other than inefficiency will have had the training which the head of the department should be able to give most effectively. In general the younger teacher cannot be expected to train students in the power of concentration, clear thinking and general appreciation of opportunities so well as the head of the department who should be more experienced as a teacher and in the practice of his subject.

Another question in connection with coördination is the number of courses which may profitably be given at one time. We should give fewer courses with more concentration. Instead of six or seven as now, we should give from two to four, the number varying in different schools. Under the present method the student spends little consecutive time on a course but is turned from one course to another so frequently that his attention is largely dissipated.

Professor C. R. Young: Professor McDaniel refers to the need of the head of the department giving more attention to the work of instruction. There are other ways than those which he mentioned specifically in which the work of teaching may be slighted.

For example. there is a great deal of research work done by members of teaching staffs that should not be done. There is a great and growing tendency to lay emphasis on the research work of the teaching staff. Research work is important. but no one can do much of it if he has much teaching to do. More than a certain amount of research work detracts from the usefulness of the teacher to the educational institution.

Too much technical writing is another source of weakness. Every engineer should do what he can to promote the literary side of his profession. but much time now spent in preparing technical literature could be better utilized in teaching.

If a teacher of engineering is not to lose ground as a teacher, he cannot afford to give a great deal of time to private practice. The personal contact of professor with student can only be given if the former has leisure time for the purpose. A recent writer in the Bulletin states that the most valuable single item in academic efficiency is the preservation of a considerable amount of leisure for the teaching staff. I agree with him on this point.

Professor Wm. T. Magruder: What freshman subject would Professor McDaniel suggest as a suitable one to be given by the heads of the departments of civil and mechanical engineering?

Professor McDaniel: The head of the department. on account of the pressure of administrative work, would not have time to give an extended course of instruction to the freshman or sophomore class. Any course which he would give should be of such a nature as to train the student in the correct use of English and to develop in him a professional interest in his future life work. A course of this character under the title of "seminar" is given to senior students in the department of civil engineering at the University of Illinois. In this course, each student is required to prepare papers on (*a*) the life of an eminent engineer; (*b*) a book review of an engineering book; and (*c*) a description of an engineering project. The papers are criticized and revised by the professor in charge and then read to the class by the student. A general discussion follows each paper. These papers are often made the basis of lectures by the professor on trite and correlated subjects to the class. These lectures are especially valuable in enlightening the students concerning the qualifications necessary for the successful practice of engineering. I think that such a course should be given to the freshman rather than the senior class, and special emphasis laid upon such phases as; instruction in the proper methods of study, the value of concentration, and the proper use of the English language.

A STUDY OF TECHNICAL COLLEGE CATALOGUES WITH RESPECT TO DESCRIPTIONS OF COURSES OF STUDY AND OF INSTRUCTION.

BY HENRY S. JACOBY,

Professor of Bridge Engineering, Cornell University.

As a member of the committee on advanced standing of the college of civil engineering in Cornell University for over fifteen years, a large expenditure of time and effort has been required in the attempt to evaluate the relative equivalence of courses of instruction in many of the technical colleges of the United States and Canada. These studies have emphasized the excessive diversity in the form, arrangement and description of this material as printed in the registers or catalogs of the various institutions. Many of these catalogs have no indexes whatever, while others have indexes which are more or less inadequate. The order in which the departments of instruction are arranged is sometimes alphabetical but more frequently the order has been determined by the historical development of the institution, and is therefore different in each case from the others. The lack of suitable page headings makes reference in many cases more inconvenient.

In justice to those students who transfer from one college to another either in the same or in different universities, it is important that the description of each course of instruction should be expressed in such definite technical terms and with such completeness as to its content and the methods of instruction that the head of a corresponding department in another institution may be enabled to form a fair estimate of its character and value in comparison with the course given in his own department. It is not to be expected that courses shall be identical in different institutions in widely separated parts of the country with varying needs and conditions.

The primary object of this paper, however, is to consider the manner in which this information is printed in the several catalogues with the hope that unnecessary differences may be gradually eliminated and that such a general arrangement may be finally adopted as will greatly facilitate references to the catalogs by prospective students as well as those in residence, and by members of the instructing staff in any college.

It is gratifying that some universities having a large number of colleges are publishing their announcements of courses, etc., in separate small pamphlets, so that it is no longer necessary to examine a bulky and complicated catalog to obtain the complete data desired. It also proves doubtless to be an economical arrangement with respect to the cost of printing and postage.

The term "course of study" is used in this paper to designate a list of those courses of instruction with their assigned hours and credits, arranged by years and terms or semesters, and which are required for any given academic degree, or adapted to the special needs of some group of students in case no degree is given. To indicate the marked differences in the statements of courses of study the following abstracts are presented, all of them relating to courses for civil engineering.

The following table includes a fairly representative list of statements relating to the subject of mechanics, and the accompanying details.

TYPES OF RECORDS IN COURSES OF STUDY.

Junior Year, 2d Term. Course 161.
Strength of Materials .... 17 weeks, 8 hours per week.

	Subject No.	Hours per Week. Class.	Lab.	Prep.	Units.
Second Year, 2d Semester. Theoretical and Applied Mechanics	160	4	0	6	10

Junior Year, 1st Half Year. Resistance of Materials (Civil 81), p. 81. 3 [credits].

	Hours per Week. Class.	Lab.	Equivalent.
Junior Year. 2d Term. Page 101. Exp. Eng. 6. Analytic Mechanics	4	0	10

	Weekly Periods.	Hours of Credit.	Credit Hours.
Junior Year, ——. Engineering Mechanics, 49 (50)	2 and 3	2	5

		[Rec. Hrs.] [Lab. Hrs.]
Junior Year, Winter Term. Applied Mechanics, II C. E.	6	(4 — 4)

	Lectures.	Laboratory.
Junior Year, 1st Semester. Math. 20 [= Analytical Mechanics]	3	0

In courses of study the years are designated as:

Freshman; Sophomore; Junior; Senior.
First; Second; Third; Fourth.
Fourth; Third; Second; First.
Freshman; Junior; Senior (in a 3-year course).

The terms of the academic year are named as follows:

First Semester; Second Semester.
First Term; Second Term.
First Half-year; Second Half-year.
First Term; Second Term; Third Term.
Fall Term; Winter Term; Spring Term.

The subject of mechanics is indicated by the following terms:

Analytic Mechanics; Analytical Mechanics; Theoretical Mechanics; Technical Mechanics; Engineering Mechanics; Mechanics of Engineering; Structural Mechanics; Mechanics; Applied Mechanics; Theoretical and Applied Mechanics; Analytical and Applied Mechanics; Mechanics of Materials; Strength of Materials; Resistance of Materials; Strength and Resistance of Materials; Materials of Engineering; Elements of Mechanics; Elementary Mechanics; Elementary Strength of Materials.

The following items are given in the courses of study:

Official title of course of instruction; descriptive name of course; duration of course; lecture hours per week; recitation hours per week; laboratory hours per week; actual hours per week; number of exercises; number of weekly periods; units; equivalents; credits; credit hours; reference to page where the course of instruction is described; and occasionally the days and hours of the schedule, as well as the names of instructors. The official designation of courses are given either with or without the names of departments by which they are given, and with arabic or roman numerals. The order of the items referred to in this paragraph seems to include the largest possible variety in arrangement.

Apart from the record of the courses of instruction in mechanics, it is interesting to note that they are given under the direction of the following departments: Engineering; Civil Engineering; Mechanical Engineering; Electrical Engineering; Experimental Engineering; Structural Engineering; Mechanics (under a variety of names like theoretical and applied mechanics, mechanics of engineering, etc.), Physics and Mathematics.

When the 3-term system is used the credit hours must be reduced one third to make them equivalent to those of the 2-term system. In a number of cases where the 2-term system is employed the credit hours are not equivalent since in some the total number of hours for a term is 16 to 18 and in others 24½ to 28. In one case (No. 29) the total number is 46 hours but these are actual hours, including time allowed for lesson preparation and for writing reports.

The differences in requirements in the fundamental courses of mechanics and hydraulics are indicated in the following tables, which were compiled from the catalogues dated 1912–13, containing the announcements for 1913–14, for most of the colleges in the United States which give courses in engineering. In the table for mechanics it was not the intention to include the topic of mechanics which usually forms a part of the general course in physics. In the table for hydraulics it was not intended to include applied hydraulics usually called hydraulic engineering, nor laboratory work of an advanced character beyond that which frequently accompanies or follows the recitation or lecture course on theoretical hydraulics and hydraulic motors in order to illustrate the theory. The tables may contain some errors since the limits of each course were not always clearly defined. The titles inserted which are enclosed by brackets were taken from the corresponding descriptions of courses.

The courses of instruction are usually grouped by departments, and arranged in regular numerical order in each group. The following extracts illustrate the range of diversity in the description of courses of instruction. Some typical descriptions of courses in mechanics and in hydraulics are given below.

University of Florida.

Names of Courses.	Nature of Work.	Hrs. per Week, Semester. 1st.	2d.
Draw. III.	Mech. Draw. to scale (3 actual hrs.)	1½	1½
Elect. Eng. Ia.	Elem. general course	3	0
Graphic Statics I.	Elem. graphics; Roofs (5 actual hrs.)	0	2½
Hydraulics I.	Elements of Hydrs.	0	3
Maths. IV.	Solid Analy. Geom. & Calc.	2	2
Mechanics I.	Mechanism (4 actual hrs.)	2	2
Mechanics II.	Analy. Mechanics	4	0
Mechanics III.	Strength of Materials	0	4
Munic. Eng. I.	Roads and Pavements	2	0
Railroads II.	Prelim. & Final Location (6 actual hrs.)	3	0
Spanish II.		3	3
Surveying III.	Higher Surveying	0	2½
		20½	20½

Catholic University.

THIRD YEAR.

First Half-year. Subject.	Half-Credits.	Second Half-year. Subject.	Half-Credits
Mathematics V. Calculus, adv. course.	4	Mechanics III. Applied Mechanics.	4
Mechanics III. Applied Mechanics.	4	Astronomy II. Practical Astron.	3
Astronomy I. General Astronomy.	3	Civil Engineering II. Higher Surveying.	2
Civil Engineering II. Higher Surveying.	2	Civil Engineering IV. Railroad Surveying.	4
Civil Engineering III. Highway Engineering.	2	Civil Engineering V. Materials of Construct.	2
Civil Engineering IV. Railroad Surveying.	4	Civil Engineering VI. Theory of Struct. 1st course.	3
Philosophy I. Introduction to Philos.	3	Civil Engineering X. Theoretical Hydraulics.	4

Religion III.	1	Philosophy I.	3
Comparative Religion.		Introduction to Philos.	
		Religion III.	1
		Comparative Religion.	
		Total credits for the year	24½

Delaware College.

SENIOR YEAR.

First Term.	*P.	H.	C.	Second Term.	P.	H.	C.
Geology, 2	45	3	3	Civil Eng., 12	57	3	3
Civil Eng., 3	55	4	4	Civil Eng., 3	55	4	4
Civil Eng., 4	55	4	4	Civil Eng., 4	55	4	4
Civil Eng., 5	56	2	2	Civil Eng., 5	55	2	2
Civil Eng., 9*a*	56	4	3	Civil Eng., 9*a*, *b*	56	4	3
Civil Eng., 13	57	2	1	Civil Eng., 13	57	2	1
Civil Eng., 14	57			Civil Eng., 14	57		
Military Science, 4	62	3	2	Military Science, 4	62	3	2
Options, one to be taken				Options, one to be taken			
Civil Eng., 7*a*, *b*, *c*	56	5	3.5	Civil Eng., 7*a*, *b*, *c*	56	5	3.5
Civil Eng., 11	56	3	3	Civil Eng., 10	56	3	3
			26.5				25.5

University of Nevada.

JUNIOR YEAR.

First Semester.	Lab.	Lec.	Second Semester.	Lab.	Lec.
Civil Eng., 21	2	2	Civil Eng., 21	2	2
Civil Eng., 29	2		Civil Eng., 26		3
Mathematics, 20		3	Civil Eng., 27	1	2
Mathematics, 21		2	Mathematics, 20		3
Electrical Eng. 21 or Geology 21		3	Mathematics, 21		2
Elective		4	Elective		3
Total		18	Total		18

Summer School of Mine Surveying (Civil Eng., 32), 4 weeks, 3 credits.

Louisiana State University.

JUNIOR CLASS.

	Hours a Week.		Number of Course.	
	1st Term.	2d Term.	1st Term.	2d Term.
Astronomy	3	—	1	—
Civil Engineering	4	4	3	4
Civil Engineering	3	3	9	10

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* The letters represent pages, hours, and credits, respectively.

Civil Engineering	6	6	9	10
Mathematics	3	3	9	10
Mechanical Eng.		3	—	12
Physics	2	2	5	6
Physics	2	2	9	10
Physics	2	2	7	8
	25	25		

Cornell University (slightly modified).

JUNIOR YEAR.

Page.		Course No.	1st Term.	2d Term.
17	Political Economy	H. & P. S. 51	3	3
26	Railroads	C. E. 60	4	4
28	Bridges	C. E. 71	4	4
21	Hydraulics	C. E. 23	3	3
25	Municipal Engineering	C. E. 52	—	3
20	Survey Computations and Mapping	C. E. 14	4	—
			18	17

REQUIRED COURSES IN MECHANICS.

No. of Col.	Year.	Term.	Statement in Course of Study for Civil Engineering.
1	Junior	2d*	Mechanics of Materials (Engineering 110) 5
		3	Mechanics of Materials (Engineering 110) 5
5			
6	Third	1	Civil Engineering 7. Analytical Mechanics, 3 class hrs.
			Civil Engineering 8. Mechanics of Materials, 2 class hrs.
7	Junior	1	Course 161. Applied Mechanics, Strength of Materials, 17 weeks, 8 hrs. per wk.
		2	Course 161. Strength of Materials, 17 weeks, 8 hrs. per wk.
8	Second	2	Theoretical and Applied Mechanics, Course 160, 4 class hrs. [See notes.]
		3	Strength of Materials, Course 162, 4 class hrs. for half term. [See notes.]
10	———	1	2*a*. Mechanics of Materials 5
11	Sophomore	2	Technical Mechanics (C. E. 5*a*) 2
	Junior	1	Technical Mechanics (C. E. 5*b*) 3
		2	Applied Mechanics (C. E. 6) 3

* Three terms per year.

Required Courses in Mechanics (*continued*).

12	Junior	1, 2	Mechanics (Mathematics 12), p. 69,	3 and 3
		1, 2	Resistance of Materials (Civil 81), p. 81	3 and 2
14	Senior	1, 2	Mechanics, C. E. 53..	3 and 1 recitations.
	[Third]	1, 2	Strength of Materials, M. E. 60, 2 rec. + 2 draw. or lab. each term.	
15	Senior	1, 2	[Mechanics of Materials], Civ. Eng. 4, p. 55	4 and 4
16	Second	1, 2	Mechanics I, Theoretical Mechanics, 3 and 3 half-credits.	
	Third	1, 2	Mechanics III, Applied Mechanics, 4 and 4 half-credits.	
17	Junior	—	Applied Math., 20, 22, Mechanics; Mechanics of Materials	—
19	Junior	1	Mechanics II, Analytical Mechanics, p. 162	4
		2	Mechanics III, Strength of Materials, p. 162	4
	Senior	1	Mechanics IV, Analytic Mechanics, p. 162	4
20	Senior	—	Civ. Eng. C 1–2–3–4 [Applied Mechanics, Hydraulics, Bridges, Arches and Reinforced Concrete, Water Supply, and Sewerage]	credits 6
21	Junior	2	p. 101, Exp. Eng. 6, Analytic Mechanics,	4 class hrs.
			p. 125, Mech. Eng. 12, Mechanics of Materials	3 class hrs.
			p. 125, Mech. Eng. 13, Mechanics of Materials	2 class hrs.
23	Junior	1, 2	Phys. 105, 106, Analytic Mechanics.	3 and 3
		2	C. E. 24, Mechanics of Engineering	4
24	Sophomore	1, 2	Analytical Mechanics, p. 68	4 and 4
		2	Strength of Materials, p. 68	4
26	Sophomore	2	Analytic Mechanics, C. E. 20	3
	Junior	1	Mechanics of Materials, C. E. 21	4
27	Fourth	—	Structural Mechanics, Engineering D 3.	3
28	Second	2	Theor. and Appl. Mech. 7, Analytic Mechanics	3

Required Courses in Mechanics (*continued*).

	Third	1	Theor. and Appl. Mech. 8, Analytic Mechanics	2½
		1	Theor. and Appl. Mech. 9, Resistance of Materials	3½
29	Junior	1, 2	Applied Mechanics 1, 2; p. 101, p. 119 [4 credits] points	10 and 10
30	Junior	1, 2	Analytic Mechanics, p. 132, Course IX,	5 and 2
		2	Mechanics of Materials, p. 132, Course X	3
31	Junior	1, 2	III, VI, Analytical Mechanics	3 and 3
		2	IX, Strength of Materials	1
32	Senior	1	VI, Applied Mechanics	3
33	Junior	[1, 2]	Engineering Mechanics (49, 50), 2 and 3 weekly periods. [See notes.] [Mechanics] Materials of Engineering (Engin. 58), 5 weekly periods. [See notes.]	
35	Junior	1	Mechanics 50, Mechanics	5
		2	Mechanics 51, Strength of Materials	4
36	Junior	Fall*	Applied Mechanics I, 4 rec. hrs., 2 lab. hrs.	5
		Winter	Applied Mechanics II, C. E., 4 rec. hrs., 4 lab. hrs.	6
37	Sophomore	1*	Appl. Mech. and Hyd. I, p. 137, Elementary Strength of Materials.	credits, 2.0
		1	Appl. Mech. and Hyd. II, p. 138, Elementary Mechanics	0.8
	Junior	1	Appl. Mech. and Hyd. III, p. 138, Advanced Strength of Materials	2.0
		2, 3	Appl. Mech. and Hyd. IV, p. 138, Analytical Mechanics	3.0
38	Junior	2	Mech. Eng. 12 [Mechanics of Materials]	3
39	Junior	1	M. & M. 33, Analytical Mechanics	3
		1, 2	M. & M. 31, 32, Mechanics of Materials and Graphics	4 and 3
40	Junior	1, 2	Mechanics, 5, 6	5 and 5
43	Second	2	Applied Mechanics (60) [Statics, Stresses in Frames, Dynamics]	45 exercises
	Third	1	Applied Mechanics (66) [Strength of Materials]	60 exercises

* Three terms per year.

Required Courses in Mechanics (*continued*).

45	——	1 or 2	Eng. Mech. 1. Kinematics and Statics, Elements of Graphical Statics	4
		1 or 2	Eng. Mech. 2, Strength of Materials	3
		1 or 2	Eng. Mech. 3, Dynamics	3
46	Junior	Fall*	C. E. 4*a*, Mechanics of Engineering	5
		Winter	C. E. 4*b*, Mechanics of Engineering	5
		Spring	C. E. 4*c*, Strength of Materials	5
47	Junior	1	Math. and Mech. 5, Calculus and Mechanics	3
		2	Math. and Mech. 6, Analytical Mechanics	3
	Senior	1	Math. and Mech. 7. Strength and Resistance of Materials	4
50	——	—	103. Mechanics of Engineering	4
52	Sophomore	2	Statics. Mech. 1 recitations	3
	Junior	1	Stresses and Strains. Mech. 2	3
		2	Dynamics. Mech. 3	4
53	Junior	1. 2	Mechanics (C. E. 5)	4 and 4
54	Sophomore	2	Mechanics, C 20	3
	Junior	1	Mechanics, C 21	3
		1. 2	Applied Mechanics, C 22, C 23	3 and 3
55	Second	2	Applied Mechanics (Theoretical and Applied), 14	3
	Third	1	Applied Mechanics (Mechanics of Materials), 15	3
56	Junior	1, 2	Math. 20 [Analytical Mechanics], lectures,	3 and 3
		1, 2	Math. 21 [Mechanics of Materials], lectures,	2 and 2
57	Junior	1	Mechanics 254 [Calculus and Mechanics]	5
		2	Mechanics 255	4
		2	Mechanics of Materials 309	3
58	Sophomore	2	Math. 206, Analytical Mechanics	2
	Junior	1	Math. 305, 306, Analytical Mechanics.	3
		2	Civ. Eng. 302. Mechanics of Materials.	4
60	Third	1. 2	[Phys. and E. E.] II 4. Mechanics, class hours.	4 and 4
		2	[C. E.] IV 6, Strength of Materials. class hours,	5
61	Junior	1. 2	311, 312. Applied Mechanics	5 and 3

* Three terms per year.

Required Courses in Mechanics (*continued*).

62	Sophomore	1	Elements of Mechanics, 30 2
	Junior	1	Analytical and Applied Mechanics, 99. 5
		2	Mechanics of Materials, 31 3
63	Sophomore	1, 2	C. E. 20, Mechanics of Engineering, 5 and 5
64	Second	2	p. 109, Mech. 102, Analytical Mechanics, 5 class hrs.
	Third	1	p. 77, Civ. Eng. 53, Resistance of Materials .... 5 class hrs., 3 lab. hrs.
		2	p. 77, Civ. Eng. 54, Resistance of Materials (Problems) .... 3 lab. hrs.
65	Sophomore	2	Mechanics, 94 3
	Junior	1	Mechanics of Materials, 95 3
		1	Analytical Mechanics, 96 2
66	Sophomore	2	M. S. 2, Theoretical and Applied Mechanics .... lecture hrs. 5
	Junior	1	M. S. 3, Mechanics of Materials, lecture hrs. 5
67	Sophomore	2	Theoretical Mechanics (Mech. 1) 2
	Junior	1	Theoretical Mechanics (Mech. 4) 2
		1	Applied Mechanics (Mech. 5) 3
68	Second	1, 2	Mechanics (Math. VII, VIII) . . 3 and 3
	Third	1	Mechanics (S. D. I) 5
69	Second	2	Applied Mechanics (60) [Statics, Stresses, in Frames, Dynamics] ... 45 exercises
	Third	1	Applied Mechanics (66) [Strength of Materials] .... 60 exercises
70	Sophomore	1, 2	Math. 3A, Elementary Mechanics. 2 and 2
	Junior	1, 2	Math. 4. Calculus and Analytical Mechanics .... 3 and 3
	Senior	1, 2	Math. 8, Mechanics of Materials. 3 and 3
71	Junior	1, 2, 3*	Mechanics, 204 .... 3, 3 and 3
	Senior	1	Mechanics of Materials, 215 3
72	Junior	Fall*	M. E. 30 [Analytical Mechanics] 5
		Spring	M. E. 31 [Mechanics of Materials] ... 5
73	Junior	—	Mechanics ([M. E.] 61, 62) 8
75	Sophomore	2	Mechanics of Engineering, Appl. Math. 2 4
	Junior	1, 2	Dynamics, Appl. Math. 3 ..... 2½ and 3
76	Sophomore	2	Applied Mechanics, Appl. Mech. 21, 17 weeks, 4 hrs. per week

* Three terms per year.

Required Courses in Mechanics (*continued*).

	Junior	1	Applied Mechanics. Appl. Mech. 22, 17 weeks, 5 hrs. per week	
79	Third	1	Mech. 51 [Mechanics]	4
		1	Mech. 52 [Applied Mechanics]	2
		2	Mech. 53 [Mechanics of Materials]	4
80	Junior	Winter*	Civ. Eng. 10*a* (Applied Mechanics)	5
		Spring	Civ. Eng. 10*b* (Applied Mechanics)	4
	Senior	Fall	Civ. Eng. 18 (Strength of Materials)	3
81	Junior	1	Statics and Dynamics (M. E. 200)	4
		2	Strength of Materials (M. E. 201)	2
81	Junior	1, 2	Math. 17 (Analytical Mechanics)	3 and 3
		2	Struct. Eng. 42 (Strength of Materials)	4
83	2d [Jun.]	Winter*	Mechanics, Rational	—
		Spring	Mechanics of Materials	—
	1st [Sen.]	Fall	Mechanics of Materials	—
84	Sophomore	3*	Applied Mechanics, 621	4
	Junior	1	Applied Mechanics, 622	4
		1, 2	Mechanics of Materials, 623, 624	4 and 4
85	Junior	—	C. E. 5, Mechanics, Statics	periods, 3
86	Junior	1*	Mechanics	[5]
		1	Strength of Materials	[5]
87	Sophomore	1, 2	Mechanics [Math.] 93	3 and 2
	Junior	1	Mechanics and Strength of Materials [Math.] 94	2
		1	Analytical Mechanics [Math.] 94	2
88	———	1, 2	(413) Strength of Materials	4 and 4
89	Sophomore	2	Analytic Mechanics, p. 254, Phys. 20	3
	Junior	1	Mechanics of Materials, p. 181, C. E. 40.	5
90	Sophomore	Summer*	Mech. 1 [Analytical Mechanics], p. 164,	5
	Junior	F. or W.	Mech. 2 [Mechanics of Materials], p. 164	5
91	Sophomore	2	Analytic Mechanics, 147	2
	Junior	1	Strength of Materials, 172	4
92	Sophomore	2	Mchs. 1, Elementary Mechanics	3
	Junior	1	Mchs. 2, Applied Mechanics	5
93	Junior	1, 2	p. 128, Mech. Eng. 215, Mechanics of Materials	class hrs., 3
		2	Math. 257, Analytic Mechanics,	class hrs., 3
94	Junior	1, 2	Applied Mechanics (Mech. Eng. X)	5 and $1\frac{2}{3}$

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* Three terms per year.

Required Courses in Mechanics (*continued*).

95	Junior	1, 2	Mechanics 1, 2 [Mechanics of Solids], —
96	Junior	2, 3*	Mechanics ([M. E.] 211) ..... 3 and 2
	Senior	1	Mechanics of Engineering ([M. E.] 212) 2
97	Second	1, 2	Mech. 1, Elementary Mechanics. Elementary Strength of Materials ...... [?] 6
	Third	—	Mech. 2, Theoretical Mechanics ... [?] 6
		1	Mech. 3, Strength of Materials ... [?] 6
98	Junior	2	Analytic Mechanics, *a*, Math 14 3
		2	Mechanics of Materials, *a*, M. E., 16.. 5
99	Junior	1, 2	Mechanics of Engineering ..... 3 and 3
100	Junior	1, 2	Theoretical Mechanics, 5, 6 .... 3 and 3
	Senior	1	Theoretical Mechanics, 7 3
102	Sophomore	1	Mechanics 1 [Statics with Application to Stresses] .... recitations, 3
		2	Mechanics 2 [Mechanics of Materials], recitations, 3
	Junior	1	Mechanics 3 [Dynamics], 3 recitations, 3 hrs. practice
104	Sophomore	Spring*	Mechanics (C. E. 1265) 3
	Junior	Fall	Applied Mechanics (C. E. 32) 3
		Winter	Applied Mechanics (C. E. 32) 3
105	Junior	1	Civ. Eng. 6, Mechanics of Materials... 4
106	Junior	1, 2	Engineering 3 (Mechanics) .... 4 and 4
107	Junior	A	Applied Mechanics [Theoretical Mechanics] 4
		B	Applied Mechanics [Mechanics of Materials 4
108	Sophomore	1, 2	Mechanics [Technical Mechanics]. 2 and 3
	Junior	1, 2	Mechanics of Materials, 4 ..... 3 and 3
109	Third	2, 3*	Mechanics of Engineering (365), 3 and 6
	Fourth	1, 2*	Mechanics of Materials (366).. 3 and 3
110	Junior	Fall*	Mechanics. Statics and Elementary Dynamics (500) 3
		Winter	Mechanics. Dynamics of a Particle (501) 3
		Spring	Mechanics. Dynamics of a Rigid Body (502) 3
	Senior	Fall	Mechanics. Strength of Materials (503), 3
111	2d [Jun.]	1	Analytical Mechanics, Mech. of Eng. I, 6

* Three terms per year.

Required Courses in Mechanics (*continued*).

		2	Mechanics of Materials, Mech. of Eng. II	3
113	Junior	1	Theoretical Mechanics (C. E. 9)	5
		2	Applied Mechanics (C. E. 29)	4
114	Junior	1, 2	Civ. Eng. 41, 42 (Mechanics)	4 and 3
117	Second	2	Statics (Engineering 70)	3
	Third	1	Mechanics of Materials (Engineering 71)	4
		2	Kinetics (Engineering 72)	3
118	Second	1	Mechanics 1. Statics	3
		1, 2	Mechanics 2, 3. Mechanics of Materials,	2 and 3
		2	Mechanics 4. Dynamics	2
120	Junior	1	Math. V (Theoretical Mechanics)	5
		2	Math. VI (Applied Mechanics)	5

Notes.—No. 8, see types of records following the next table, second entry; No. 33, see types of records, fifth entry.

REQUIRED COURSES IN HYDRAULICS.

1	Senior	2*	Theoretical Hydraulics (Eng. 116)	5
		3	Practical Hydraulics (Eng. 117)	4
5				
6	Third	2	C. E. 9. Hydraulics	class hrs., 3
7	Junior	2	Hydraulics (306).	17 weeks, 5hrs. per week
8	Third	1	Hydraulics, 230, (see notes)	class hrs., 4
		2	Hydraulic Motors, 232. (see notes)	class hrs., 2
		2	Hydraulics Laboratory, 231	lab. hrs., 3
			Hydraulic Machinery, 233	lab. hrs., 3
10	———	2	3. Hydraulics, *a.* Hydrostatics and Hydraulics	3
	———	1	3. Hydraulics, *b.* Hydraulic Motors	3
11	Senior	1	Hydraulics (C. E. 7)	2
12	Junior	1	Hydraulics (Civil 41), p. 80	2
		1	Hydraulic Laboratory (Civil 42), p. 80.	1
14	Sen. [3d]	2	Hydraulics, C. E. 54	recitations, 2
15	Senior	1, 2	Hydromechanics 3, p. 55	4 and 4
16	Third	2	Civ. Eng. X, Theoretical Hydraulics.	half-credits, 4

* Three terms per year.

Required Courses in Hydraulics (*continued*).

17	Senior	—	Appl. Math. 21. Hydraulics .... —
19	Junior	2	Hydraulics I. Elements of Hydraulics, p. 157 3
20	Senior	—	Civ. Eng. C 1–2–3–4 [Applied Mechanics; Hydraulics; Bridges, Arches and Reinforced Concrete; Water Supply and Sewerage] .... credits, 6
21	Junior	1	Page 67, Civ. Eng. 15. Hydraulics, class hrs., 3
		2	Page 104, Exp. Eng. 18. Hydraulic Laboratory .... lab. hrs., 4
23	Junior	2	C. E. 28. Hydraulics .... credits, 3
24	Junior	1	Hydraulics, p. 69 5
26	Junior	2	Hydraulics, C. E. 16 2
27	Fifth	1	[Hydraulics is probably included in Hydraulic Engineering.]
28	Third	2	Theor. and Appl. Mech. 10. Hydraulics, 3
29	Junior	2	Hydraulics, 42, p. 118 .... points, 5
		2	Hydraulic Laboratory, 59, p. 119, points, 3
30	Senior	1, 1	Hydromechanics, XVI, p. 136 .. 3 and 3
31	Senior	1	VII, Hydraulics 2
32			
33	Junior	—	Hydraulics and Hydraulic Machinery (Engin. 31) 5
35	Senior	1	Civ. Eng. 68. Hydraulics 3
		1	Civ. Eng. 60. Hydraulic Laboratory.. 1
36	Junior	Spring*	Hydraulics (3—2) 4
37	Junior	1*	Appl. Mech. and Hyd. V. Hydraulics, credit, 0.8
38	Senior	1, 2	Civil Engineering 11, 20 [Hydraulics], 2 and 2
39	Senior	1	Hy. E. 41. Hydraulics 4
40	Junior	2	Civil Engineering 10 [Hydraulics] ... 3
43	Fourth	1	Theoretical Hydraulics (330), 45 exercises
		2	Hydraulic Laboratory (342), 15 exercises
45	———	1 or 2	Civ. Eng. 11. Hydraulics 2
		1 or 2	Eng. Mech. 4. Hydromechanics 2
46	Senior	Fall*	C. E. 5. Hydraulics 5
			C. E. 5*a*. Hydraulic Laboratory...... 2
47	Senior	2	Math. and Mech. 8. Hydraulics 4

* Three terms per year.

Required Courses in Hydraulics (*continued*).

52	Junior	2	Hydraulics, Civ. Eng. 44.. recitations,	3
53	Junior	1	Hydraulics (C. E. 8)	3
54	Junior	2	Hydraulics, M. 50	3
		2	Hydraulic Laboratory, M. 52	1
55	Third	1	Civil Engineering (Hydraulics) 11	2
56	Senior	1	Civ. Eng. 28 [Hydraulics] .. lectures,	2
57	Senior	1	Hydraulic Engineering, 313	3
		2	Hydraulic Laboratory, 320	1
58	Senior	1	Civ. Eng. 405. Hydraulics	2
60	Fourth	1	VIII, 12. Hydraulics ..... class hrs.,	3
61	Junior	2	356. Hydraulics	3
62	Junior	1	Theoretical Hydraulics, 38	3
63	Junior	1, 2	C. E. 23. Hydraulics	3 and 3
64	Fourth	1	Page 79, Civ. Eng. 75. Hydraulics, class hrs.,	4
		1	Page 95, M. E. 63. Hydraulics Laboratory lab. hrs.,	3
65	Senior	1	Hydraulics, 33	2
66	Senior	1	M. S. 9. Hydraulics .... lecture hrs.,	2
		2	M. S. 9. Hydraulic Motors and Machinery lecture hrs.,	2
67	Junior	2	Hydraulics (Mechanics 3)	3
68	Third	1, 2	Hydraulics (H. I.)	3 and 3
69	Fourth	—	Hydraulics; Hydraulic Laboratory; Aerodynamics	—
70	Senior	1, 2	Math. 7A. Hydraulics and Sanitary Engineering	3 and 3
71	Senior	2, 3*	Hydraulics 216	2 and 2
72	Junior	Winter*	C. E. 8. [Hydraulics]	5
73	Senior	—	Hydraulics (M. E. 67)	2
		—	Hydraulics (M. E. X. 44) [Hydraulic Laboratory]	2
75	Junior	1	Hydraulics, C. E. 13	3
76	Junior	2	Hydraulics, Appl. Mech. 25,	17 weeks, 4 hrs. per week
	Senior	1	Hydraulic Laboratory, Appl. Mech. 26,	8 weeks, 3 hrs. per week
77	Third	2	Mechanics (102), Kinetics and Hydraulics	5
79	Third	2	Mech. 55 [Theoretical Hydraulics]	3

* Three terms per year.

Required Courses in Hydraulics (*continued*).

80	Senior	Fall*	Civ. Eng. 11 (Hydraulics),	3 class hrs., 2 lab. hrs.
81	Junior	2	Hydraulics (M. E. 202)	2
		2	Hydraulic Laboratory (Exp. Eng. 141),	1
82	Senior	1	Hyd. Eng. 61 (Hydraulics)	4
83	1st [Sen.]	Fall*	Hydraulics	—
84	Junior	3*	Hydraulics, 661	3
		3	Hydraulic Laboratory, 663	1
	Senior	1	Hydraulics, 662	3
		1	Hydraulic Field Work, 664, 2 afternoons	
85	Junior	2	C. E. 10. Hydraulics	periods 3
86	Senior	2*	Hydraulic Motors [Hydraulics, etc.],	[5]
87	Senior	1	Hydraulics, 32	3
88	———	1, 2	Hydraulics	2 and 2
89	Junior	1	Hydromechanics, p. 180, C. E. 25	3
		1	Hydraulic Testing, p. 181, C. E. 26	3
90	Junior	Spr. or Sum.*	San. Eng. 1, p. 181 [Hydromechanics and Hydraulics]	4
		Spr. or Sum.*	San. Eng. 2, p. 181 [Hydraulic Laboratory]	3 lab. hrs., 1
91	Junior	2	Hydraulics, 177	3
		2	Hydraulic Laboratory, 187	1
92	Junior	1	Hyd. 1. Hydraulics	2
		2	Hyd. 3. Hydraulic Laboratory	1
93	Senior	1	Page 129, Engineering 225. Hydraulics,	class hrs., 3
94	Junior	2	Hydraulics (Mech. Eng. XI)	$3\frac{1}{3}$
95	Senior	1	Mechanics 3 [Mechanics of Fluids]	—
		2	Mechanics 4 [Applied Hydraulics = Hydraulic Motors]	—
97	Fourth	1	Hydraulics and Water Power	[?] 3
98	Junior	1	Hydraulics, *a*. Civ. Eng. 5	3
102	Junior	2	Mechanics 4 [Hydraulics]	3
104	Junior	Spring*	Applied Mechanics (C. E. 32) [includes Hydraulics]	3
		Spring*	Hydraulic Laboratory (C. E. 128)	1
105	Junior	1, 2	Civ. Eng. 7. Hydraulics	2 and 2
106	Senior	1	Engineering 6 (Hydraulics)	4
		2	Engineering 11 (Hydraulic Laboratory),	1
107	Senior	1, 2	Hydraulics	3 and 1
		2	Hydraulic Laboratory	1
108	Junior	2	Hydraulics	2

* Three terms per year.

Required Courses in Hydraulics (*continued*).

109	Fourth	3*	Hydraulics (372)	3
110	Junior	Winter*	Mechanics. Hydrostatics and Hydraulics (504)	3
		Spring	Mechanics. Hydraulic Motors and Pumps (505)	3
		Spring	Mechanical Laboratory. Hydraulic Laboratory (555)	1
111	1st [Sen.]	2	Hydraulics, Civ. Eng. IV	3
113	Junior	1	Hydraulics (C. E. 13)	5
		2	Hydraulic Laboratory (C. E. 26)	2
114	Junior	2	Civ. Eng. 50 (Hydraulics)	4
117	Third	2	Hydraulics (Engineering 73)	2
118	Third	1	Hyd. and San. Eng. 1. Hydraulics	3
120	Junior	2	C. E. VIII (Hydraulics)	3

James Millikin University.

20. Analytic Mechanics.—Prerequisite, Calculus, 7. This course consists of the study of those problems of mechanics which are the basis of all work in engineering design. Text-book: Hancock's Applied Mechanics for Engineers. (3) 3.

University of Illinois.

7, 8. Analytical Mechanics.—The mechanics of engineering rather than that of astronomy and physics: Fundamental concepts; equilibrium and motion; engineering problems; statement of conditions and use of data. (The work begins in the second semester; in the first semester of the following year it is given concurrently with Theoretical and Applied Mechanics 9.) Maurer's Technical Mechanics. II; (3); I; (2½).

Asst. Prof. Enger, Mr. Noerenberg, Mr. Boomsliter, Mr. Seely, Mr. Ensign, Mr. Farwell, Mr. Millard.

Prerequisite: For 7, Mathematics 7, registration in Maths. 9; for 8, Maths. 0. Theoretical and Applied Mechanics 7.

Purdue University.

1. Applied Mechanics.—First semester.

Four recitation hours per week. Required of Juniors in Engineering Must be preceeded by Math. 4.

Precedes Applied Mechanics 2 and 3; Civil Engineering 11, 21, 33 and 34; Mechanical Engineering 64, 65, 66, 67, 68 and 69; and precedes or accompanies Civil Engineering 31; Mechanical Engineering 63, 72 and 73; accompanies Mechanical Eng. 61, 62.

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* Three terms per year.

This course begins with a study of the general principles of equilibrium, and their applications to jointed frames and machines. It then treats rectilinear, curvilinear and harmonic motions; the relativity of motions; force, mass and acceleration. This is followed by a study of physical properties of the common engineering materials; the stresses and corresponding deformations of these materials in tension, compression, shear; the principles underlying the investigation and design of pipes and cylinders carrying internal fluid pressures, riveted joints, beams and columns, in connection with which the center of gravity and moment of inertia of areas are studied. The strength and elastic properties of engineering materials as shown by actual tests, as well as familiarizing the student with the structural shapes as given in handbooks of the various steel companies, are given special attention. The solution by the student of a large number of practical numerical problems is an important feature of the course.

Profs. Dukes and Poorman; Messrs. Lawrence and Hudgins.

2. APPLIED MECHANICS.—Second Semester.

Four recitation hours per week. Required of Juniors in Engineering. Must be preceded by Applied Mechanics 1 and Physics 1.

Precedes C. E. 41 and 46; Mechanical Eng. 64, 65, 66, 67, 68 and 69; precedes or accompanies Mechanical Eng. 63, 72 and 73; accompanies Mechanical Eng. 61 and 62, and Civil Eng. 42.

This course continues with the study of the strength of materials in which are treated beams, columns and shafts; the kinetics of rigid bodies, including moment of inertia of masses, simple, compound, conical and torsional pendulums, centrifugal force and the balancing of machines; work and energy; impulse, momentum and impact; friction and lubrication.

Profs. Dukes and Poorman; Messrs. Lawrence and Hudgins.

State University of Iowa.

47. ENGINEERING MECHANICS. 5 hrs.

Recitations and problems in statics and kinetics. Prerequisites, Mathematics 23 (24), Physics 7 (8). Prof. Woodward.

Five two-hour periods a week.

49, (50) ENGINEERING MECHANICS. 2 and 3 hrs.

Same as 47. Prof. Woodward.

Two two-hour periods a week during first semester, and three two-hour periods a week second semester.

Massachusetts Institute of Technology.

60. APPLIED MECHANICS (Statics-stresses in Frames-Dynamics).

Profs. Johnston, Fuller, Hayward; Messrs. Smith and Holmes.

Preparation: 31 and 770, which may be taken simultaneously.

A course of three lectures (or recitations) per week in the second term of the second year for Courses I, II, VI, XI, XIII, and XIV, and in the first term of the third year for Courses III and X. The course comprises a study of statics, consisting of the general methods and applications of statics, including the determination of reactions, stresses in frames; of distributed forces, center of gravity; of moment of inertia, radius of gyration of plane areas and solids including principal axes and principal moments of inertia; of kinematics and dynamics including the equations for uniform and varying rectilinear and curvilinear motion, centrifugal force, unresisted projectile, pendulum, harmonic motion, rotation, combined rotation and translation, momentum and angular momentum, center of percussion, impact, work, power and kinetic energy.

(Required in Courses I, II, III, VI, X, XI, XIII, XIV.)

66. APPLIED MECHANICS (STRENGTH OF MATERIALS).

Profs. Johnston, Fuller, Hayward.

Preparation: 31; 60; 770.

A course of four lectures (or recitations) per week in the first term of the third year. The course comprises a study of the strength of materials as described in course 65 with additional applications to simple frames subjected to bending stresses; also a brief study of strains and the relations of the stresses on different planes.

(Required in Courses I and XI.)

University of Missouri.

103. MECHANICS OF ENGINEERING. (Prerequisite, Math. 6.) Statics, dynamics, strength of materials, hydrostatics, hydrodynamics. Lectures and recitations. (4) Mr. Defoe.

Cornell University.

20. MECHANICS OF ENGINEERING.—For sophomores in civil engineering. Throughout the year, credit five hours a term. Prerequisite mathematics, course 5. A study of the principles, and applications to engineering, of the mechanics of solids: as relating to the mutual actions, motions, pressures, strength, stiffness, and resilience of the members of structures and machines. Original problems form a prominent feature. Statics of a material point and of rigid bodies. Centers of gravity. Chains and cords. Dynamics (kinetics) of a material point. Impact. Virtual velocities. Centrifugal and centripetal forces. Pendulums. Moments of in-

ertia of plane figures and of rigid bodies. Dynamics (kinetics) of rigid bodies. Work. Power. Energy. Fly-wheels. Friction. Graphical statics of mechanism. Dynamometers. General theorem of work and energy applied to machines. Stresses and strains. Tension. Shearing. Compression. Torsion. Flexure. Elastic curves. Safe loads. Columns. Text-books; Church's Mechanics of Engineering, and Notes and Examples in Mechanics, supplemented by other printed notes and problems. Lectures and recitations, daily except S, throughout the year. Seven sections. Professor Church, Assistant Professors George and Rettger, and Messrs. Brauner and Dougherty.

Leland Stanford Jr. University.

COURSE 3. HYDRAULICS:

a. HYDROSTATICS AND HYDRAULICS.—This course treats of fluid pressure, the principles of fluid equilibrium, and the laws governing the flow of water through orifices, over weirs, in closed conduits, and in open channels. Open to students who have completed courses 2 and 3 in Applied Mathematics.

Monday, Wednesday, Friday, 9:15. 3 units, 2d semester (Hoskins).

b. HYDRAULIC MOTORS.—A discussion of the theory of the main types of turbines, including centrifugal pumps. A few lectures on the general theory of energy and on relative motion are given as an introduction to the course. Open to students who have completed course 3*a*.

Monday, Wednesday, Friday, 9:15. 3 units, 1st semester (Hoskins).

State University of Kentucky.

V. HYDRAULICS.—This course consists of text-book exercises together with the solution of numerous problems covering the principles of hydrostatics and hydrodynamic pressure, the flow of water through orifices and nozzles, over weirs and through pipes and open channels, also the loss from friction and other sources. 2 hours per week, first term (Carrel).

Massachusetts Institute of Technology.

330. THEORETICAL HYDRAULICS.

Profs. Porter, Russell.

Preparation: 60.

A course of forty-five text-book exercises given in the first term of the fourth year, with the solution of numerous problems covering the principles of hydrostatic and hydrodynamic pressure, the flow of water through orifices and nozzles, over weirs, and through pipes and open channels, and the losses from friction and other sources. The student is made acquainted with the best experimental results, and the course is supplemented by exercises in the laboratory for both Options and in the field for Option I (courses 333 and 342). Russell's Hydraulics is used as a text-book.

(Required in Courses I, XI.)

342. HYDRAULIC LABORATORY.

Profs. Miller, Taft and assistants.

Preparation: 330.

A course of eight laboratory exercises of two hours each in the second term of the fourth year. The time is devoted to testing pumps, ejectors, pulsometers, etc., to measuring water by means of weirs, meters, nozzles and orifices; and to making efficiency tests of water wheels.

(Required in Courses I, XI.)

Michigan Agricultural College.

5. HYDRAULICS. Fall term. 5 credits.

Five recitation hours per week.

Prerequisite: Civil Eng. 4*c* and Mechanical Engineering 13*b*.

Required of seniors, Engineering course.

This subject is studied as an extension of our courses in mechanics of engineering. Particular attention is given to weir measurements, flow of water in channels and pipes, and discharge through different orifices.

5*a*. HYDRAULIC LABORATORY. Fall term. 2 credits.

Four laboratory hours per week.

Prerequisite: Civil Eng. 5 must precede or accompany.

Required of senior Civil Eng. students.

Experimental investigation and verification of formulae, determination of coefficients, and study of methods applicable in measuring the flow of water, and in testing the efficiency of hydraulic motors.

Washington University.

44. HYDRAULICS.—Hydrostatic and hydraulic theory, with the application of the principles thus developed to the flow of water through orifices, pipes, channels, etc.; the determination of water power; the measurement of velocities and discharge. Three hours a week. Second semester. Junior year.

Princeton University.

CIVIL ENG. 405. HYDRAULICS. Theory. Required of all C. E. seniors first term, 2 hours a week. Prof. Smith or Mr. Condit.

Lehigh University.

177. HYDRAULICS. Hydrostatics and theoretical hydraulics. The flow of water through orifices, weirs, tubes, pipes, and channels. Naval hydro-

mechanics. Hydraulic motors. Preparation required: 320, 321, 322, 145. Second term (3).

CONCLUSIONS.

The utmost simplicity is desirable in all statements in courses of study. The statement for each course should preferably include: No. of course; title; page reference to description; and credit hours for each term.

All details relating to each course should be given in the description printed under courses of instruction arranged by departments. Such a description should give as complete a list as practicable of subdivisions or topics included; the books used; the method of instruction, whether by lecture, recitation, computation, drawing, laboratory, field work, etc., and if several methods are combined the total number of exercises devoted to each should be given; the length of exercises; the term or terms in which the course is given; the prerequisite courses required for admission to the given course; the credit hours; the names of the instructors; the room; and the schedule hours unless the last two items are printed separately for the use of students in residence.

It is reasonable to expect that the publications of educational institutions should be, at least approximately, models of clearness, directness, simplicity, and truthfulness in statement; systematic in arrangement; and thoroughly adapted to the purposes for which they are intended to be used. This subject is worthy of careful consideration by the members of this Society and it is hoped that its discussion may lead to some constructive effort to improve existing conditions through the coöperation of the institutional representatives and of other organizations which are interested in the administrative affairs of colleges of engineering.

DISCUSSION.

Professor Jacoby: After my paper was prepared I learned that the report of the Carnegie Foundation for the Advancement of Teaching contained a paper by President Pritchard on college catalogues; a most interesting paper, which I trust that all of you will read. It touches on many important matters, such as the financial resources of institutions, the numbers of teachers, etc. To emphasize the points made in the paper, Dr. Pritchard mentions names and gives facts. A table is included, based on data from a number of catalogues for 1912 and 1913, which makes some instructive comparisons.

Dean G. C. Anthony: Professor Jacoby has taken up a vital subject. Those having to do with catalogues must feel the importance of that presentation.

Professor C. E. Houghton: Some universities require one hour of work outside of the class-room, some two hours, and some more than that for one hour credit. If we are going to make any statement, we should set down the amount of time a student would be engaged in the work of that course. The number of credit hours in itself means little. If a student has put about a certain amount of time during a term on a subject, we know about what ground he has covered.

Professor G. R. Chatburn: Professor Houghton's statement strikes a fundamental note. The faculty of the University of Nebraska recently passed the following resolution: "With each subject under 'Courses of Instruction' in the catalog there shall appear a detailed statement of the time per week required of students in (*a*) attendance, (*b*) preparation. (*c*) laboratory, drawing, observation, practice, etc.; and for each three hours of the total time required, as thus stated, there shall be given one 'hour of credit.'"

Dean Anthony: That is a valuable recommendation. I have tried to carry it out and believe that this should be done generally.

GRADING OF STUDENTS BY UNIVERSITIES VS. GRADING OF TECHNICAL GRADUATES BY EMPLOYERS.

BY C. FRANCIS HARDING,
Professor of Electrical Engineering, Purdue University.

The majority of employers of technical graduates select technically trained employees upon the basis of qualities quite apart from those given prominence in university grading and credits. The majority of universities do not study sufficiently the qualifications of their graduates most desired by the employers of technical men nor do they give sufficient weight to the grading of such qualifications. These two statements represent the premises upon which the following discussion is based and, whereas they are believed to be true after a considerable study of the subject by the writer, it is recognized that their truth will not be immediately granted by the average university reader. If some evidence or suggestion may be presented which will tend to confirm these premises or possibly only to arouse the interest of other instructors in the further study of this problem it will be felt that the purpose of this paper has been fulfilled.

Efficiency in the Educational Process.

Efficiency is defined as the ratio of output to input. In the all-absorbing struggle for increased efficiency in machines, labor and employees, increased efficiency is brought about in some cases by the decrease of input for a constant output or by an increase of output for a constant input. In some cases the question of the quality, commercial value or earning capacity of the output is quite as important a consideration in determining high efficiency as the output and input themselves. No university is wide awake nor can it keep pace with manufacturing or public utility corporations of the present day that absorb its graduates if it does not make a careful study not only of the efficiency of the organization but of the possible increase in efficiency of its product. Failures to produce the highest efficiency are often charged by university faculties to too large an input for the equipment and financial resources of the institution, or more often to a grade of input too low, due to weaknesses in preparatory schools. All will agree that the amount and quality of the input cannot be governed at will by entrance requirements and it is the belief of the writer that more attention and study might well be given to the quality of the output measured in terms of requirements under which the output is to be used rather than to pay too much attention to the input or to lay the blame upon poor preparation of the raw material over which but very limited control can be exercised. This statement must not be interpreted as an excuse for low entrance requirements but rather an appeal for a continued study of the problem of the possibilities of higher efficiency in connection with the available raw material.

Student Personality Records.

Whether or not the faculty of a university believes that the requirements of the average employer are more exacting than they should be, or that it is possible to instruct the student along all the lines and develop in him the qualities desired by such employers, it will be recognized by all that if the judgment of the employer, which is sometimes based solely upon a short interview with the student, can be augmented by a recommendation from the department from which the student is to graduate, the chances of error in placing the student in the wrong line of work or of his failure in whatever line of work he selects will be greatly lessened. Recognizing this fact, it has been the custom for many years at Purdue University to obtain a majority vote of all the instructors in a given school expressing personal opinion regarding qualities of students, aside from scholarship, which are recognized to be of most importance in practically all lines of work which the student may enter after graduation. The qualities selected are these: habits, mental caliber, speed, popularity, self-reliance, accuracy, address, industry, and reliability. There are, of course, many other qualities which might well have been included in this list but it is believed that it is sufficiently comprehensive to enable a fair estimate of the student to be obtained and is not so long and detailed as to prove burdensome. These records, taken at graduation, have been used both for comparison with the impressions obtained by employers during their rather short interviews with the students and also as a basis for recommendation for many years after graduation.

A Recent Experiment in Personality Grading.

The success of the above rather incomplete method, together with the belief that the university should make more of an effort to study the weaknesses of its students and attempt to improve them, have led to a recent experiment in the school of electrical engineering as follows: A record was made twice during the senior year in a manner similar to that outlined above, the first being taken in the first semester as soon as the instructors felt sufficiently well acquainted with the seniors to make a reliable estimate of their personal qualities. These records were then discussed with such students as were interested enough to make an appointment with the head of the department for personal interviews. In such conferences an attempt was made not only to impress upon the student the desirability of studying and improving his weaknesses but also to correct from further information gained from him any errors which are made by the instructors. With this information at hand a second estimate was made late in the second semester.

One modification of the above method has seemed desirable. Whereas the department records include a grade or a question mark for habits, depending respectively upon a definite knowledge of good or bad habits or a feeling that the habits may be questionable, great care has been taken to discuss this matter with the students only when definite knowledge of the habits of the student under study is at hand. Little good can be done in discussing habits in cases where they may have been questioned largely upon an intuitive feeling rather than actual facts. Some change in our procedure should therefore be made to cover this point.

Some Results of the Grading.

When the new method was adopted a healthy interest was immediately aroused in the seniors and the study of their personal qualities was in general taken in the light in which it was presented even when the judgment of the instructors established a lower grade than was considered correct by the student in question. In the personal interviews the students were asked to state frankly what grades they considered to be in error and in most cases where changes were suggested there was considerable justification either for reconsideration of the grade immediately, or for a further careful study of the student with regard to the debated quality during the months preceding the next grading period. An unexpectedly large number of the class expressed themselves as anxious to learn of the impressions made upon the faculty and every student interviewed left the conference with at least an expressed determination to raise some or all of the grades before the next grade was to be established. It is interesting to note also that such a determination was often made by students who ordinarily have expressed little inclination to raise their scholarship grades above the value just sufficient to give them credit for the course.

Another interesting development of this method of grading was the request from the students that the class be graded independently by a representative student committee selected by the students themselves. The committee selected was made up of some of the most experienced and thoughtful men in the class. Surprising as it may seem, however, their estimates were almost invariably below those of the department.

TABLE I.

Grading of Personality Characteristics.

First Column, Department Estimate; Second, Student Estimate.

Student No.	Mental Caliber.	Speed.	Popularity.	Self Reliance.	Accuracy.	Address.	Industry.	Reliability.
1	BC	BC	BB	BC	AC	AC	AC	AC
2	AA	AB	AB	AA	BB	AB	AA	AB
3	AA	BA	BB	AA	AA	BB	AA	AA
4	BB	BB—	BB—	BB	BB	BC	AB	AB
5	AB	AB	BC	AB	AA	BC	AA	AB
			etc.					

TABLE II.

Summary of Personality Grades in Per Cent.

	1914 Class.						Average 7 Years.		
	A		B		C		A	B	C
	Dept.	Student.	Dept.	Student.	Dept.	Student.			
Habits	79		20		1		88.5	9.2	2.3
Mental caliber	40	32	53	66	7	2	39.4	53.7	6.9
Speed	28	11	65	76	7	13	31.7	58.4	9.9
Popularity	26	6	74	68	0	26	33.7	62.6	3.7
Self reliance	54	28	40	66	6	6	56.3	36.4	7.3
Accuracy	35	19	63	71	2	10	41.7	50.9	7.4
Address	32	16	62	63	6	21	34.0	57.4	8.6
Industry	54	11	35	65	11	24	53.0	37.6	9.4
Reliability	71	21	29	65	0	14	72.6	23.9	3.5

Tables I and II give these results in detail. A study of the double columns of Table I, each line of which refers by number to an individual student, will indicate the differences between student committee and departmental estimates. In all tables " A " indicates merely " above the average of the class," " B " is " average " and " C " is " below the average."

In Table II a comparison of the percentages of the three grades in the entire senior class is made, showing more forcibly the very much smaller number of " A " grades and correspondingly higher number of " B " and " C " grades in the student estimate. The last three columns indicate that the percentages of " A's " over seven years of study are not materially different from those for the 1914 class although the personnel of the department has materially changed in the meantime. This fact, together with the method of majority vote used to determine the departmental estimate tends to eliminate any bias due to partiality or lack of judgment from a practical viewpoint which might have affected the decision of any individual instructor.

DISADVANTAGES OF THE PURDUE METHOD.

Thus far no serious disadvantages have been found with this system and the only objections which might arise as to its use are, I believe, the following.

In some cases with students of particularly sensitive dispositions the fact that the judgment of the instructional corps does not rank them as high as they would expect or that this judgment is actually in error might create a feeling of resentment which could not be completely eradicated by the personal conference. Whether such a feeling would ultimately result in an improvement in the character of the student or otherwise depends largely upon the nature of the student himself. The few cases of this type thus far encountered have apparently developed a determination to improve the impression made at the time the first grades were determined upon.

The fact that in a class of seventy seniors in electrical engineering it is impossible for the majority of the instructors to be sufficiently well acquainted with all of the students to determine definitely upon their habits, prevents the greatest possible amount of good being done by this method. This fact, however, offers no reasonable excuse for failing to attempt as much as is found possible and usually the cases most deserving of personal attention are those in which the facts are quite forcibly impressed upon the minds of the instrucors by the actions of the students.

One condition which was not anticipated and which upon first sight would be recognized as a disadvantage to this system was that the majority of the students immediately compared notes among themselves with regard to their grades. In some cases this unexpected procedure led some individual students to believe that the knowledge of the instructors was superficial or prejudiced. In most cases, however, it resulted either in a second conference upon the initiative of the individual student whose grade appeared low, often accompanied by a friend who interceded for him; or a determination to convince the instructors at the next grading period that they were in error in their estimates. Both of these results seem to work out as advantages of the method rather than otherwise.

Possible Objections to the Method.

It will immediately be argued by those engaged in university work where the classes are large that the time required for such an investigation as that described is too great. The only answer to this argument is that no time can be more efficiently used by any instructor in any university than that which he spends in determining and attempting to improve the personal qualities of the students with whom he comes in contact. If he is engaged in instructional work for purely altruistic motives and is to become a successful instructor, his ambition to improve the quality of the output of the university and to increase the efficiency of its graduates not merely from a scholarship standpoint but also in all the qualities herein set forth is not only most commendable but well worthy of considerable extra time.

Summary and Conclusions.

The advantages of this system, aside from those which have been incidentally set forth above, may be briefly stated as follows:

It suggests to the students, often for the first time, the qualifications aside from scholarship, which are of prime importance for their own training and welfare and upon which they are judged by those to whom they are to apply for employment in the future.

It arouses in the students an interest in correcting their weaknesses in these various qualities and their interest along these lines seems to exceed, on the average, that expressed in obtaining high scholarship grades.

It corrects errors in judgment of the student by the instructor and assists the student who may have inherent good qualities but who, for some minor reason, is unable to make such qualities recognized by those with whom he comes in contact.

It offers the best possible opportunity for personal conference between students and instructors and particularly with the head of the department, who makes it a point to discuss these matters in detail with each student who expresses a desire to do so.

It broadens the judgment of the younger and less experienced instructors and permits them, sometimes for the first time, to judge students from the same viewpoint taken by employers. Too often instructors, particularly those in academic departments or those who have not had actual experience in practice, make the mistake of judging students purely from the standpoint of scholarship.

It offers a much fairer basis for recommendation of students not only to employers with whom they are to come in contact during the senior year but also for positions in later years. The records are obviously fairly accurate after having been taken twice in the senior year, especially when such records are discussed with the respective students.

Further, it is hoped that this method will be of great assistance to employers, since the writer knows from experience that the employer dislikes to offer a position to a student entirely upon the basis of a comparatively short personal interview and he further hesitates to give very much weight to the recommendation of the instructor since this is too often based to great extent upon a scholarship record.

In conclusion the results are such as stated and the predictions which the writer ventures to express in writing for the first time may be interpreted as the hallucinations of a dreamer. He firmly believes, however, that out of the present rather serious, and to a large extent justified, criticisms of the employers of technical graduates which have been showered upon the universities in the last decade will come an awakening of the university to the fact that it is not so large and unsympathetic that it cannot in the future take rather radical steps to improve the standard of its graduates. It will thereby increase their possibilities for success when turned out of its gates into a world which demands for success in practically every profession not only the best scholastic preparation but also the best possible standing in personal qualities. If in the future this study can be carried into all four years of the university life of the student and if one person, preëminently qualified for such work, can be appointed upon the university staff to make such studies of all students and to suggest to the students themselves or to the instructors possible improvements in the qualities of the individual or the class as a whole, it would result in one of the most important efficiency campaigns yet inaugurated. If the large manufacturing and public utility corporations would also establish a department or employ an individual to make the same careful studies of their employees that they make of their raw material and their product in process of construction, and would coöperate as far as the technical employees are concerned with the universities furnishing such employees, and if they would feel frank to criticize in sufficient detail the training and qualifications of graduates supplied to them by the university it is believed that not only the efficiency of the university and the corporation per se might be improved but the combined efficiency of both working as a unit would be greatly augmented and each would appreciate better the difficulties under which the other is working.

Discussion.

Dr. Wm. Kent: When the data given in Professor Harding's paper are put into graphical form they appear as shown in the accompanying diagram. Professor Harding stated that the order in which the student qualities are placed in the tables was selected without regard to their importance. In examining these qualities to determine if they had some cause and effects relation I found that they could be divided into two parts. First there are the moral qualities: habits, reliability, industry and self-reliance, and second, there are the mental, physical and social qualities: mental caliber, speed, accuracy, address and popularity.

In an engineering salesman two important qualities are address and popularity. Whether or not accuracy in statement is wanted depends upon his employer. The engineering salesman is concerned with speed, while of mental caliber he needs only enough to hold his own with the man to whom he is trying to sell goods. But in the case of a designer of dynamos, one would demand mental caliber, reasonable speed and high accuracy. His employer would not care whether he had address or was popular for he would be hidden away in a drafting room. Evidently then success in salesmanship would come from a very different set of qualities from those needed in a designer.

Referring to the diagram it appears that the A men, the best students, are ranked very high by the professors in habits and in reliability. They are ranked far above the B men in the qualities of industry and self-reliance. But these men are the ones that the professors register low in mental caliber, speed, accuracy, address and popularity.

Now take the B men as judged by the professors, they are very low in habits and reliability, below the A men in industry the verdicts is due to the personal equation of the judges, and what is now needed is an investigation of this personal equation. I suggest that it be tested in the following manner: Let five professors, five A men and five B men, selected as representative students of a class and be taken as judges, fifteen judges in all, and let them pass judgment on ten students whose rating is from A to C. Tabulate all the judgments, and let each of the fifteen judges plot on ten pieces of transparent cross section paper on a given scale his judgment for the nine stated qualities each of the ten students judged. We will thus have 150 plottings in all. If the ten plottings of each judge be superposed and blue-printed, we will obtain what may be called a composite picture of his judgments, and from it we may learn something of his personal equation as a judge. On each of these pictures an average curve may be drawn which will show his average judgment on each of the nine qualities. By tracing on one sheet the fifteen curves obtained we may learn something as to the peculiar tendency of any judge in regard to any one of the nine qualities. It may be found that some of the judges are incompetent judges of one or more of these qualities. By sorting the 150 plottings in different lots, we can obtain composite pictures of different combinations, such as the judgment of the three classes of judges separately or the qualities of the A, B and C men.

After all the judgments are tabulated and conclusions drawn from them the ten students might be judged by psychological tests, say by Professor Munsterberg and Dr. Catherine Blatchford, and their verdicts concerning the men compared with those of the judges. I wish Professor Harding would undertake some such investigation as I have suggested and present the results in a paper at another meeting.

Dean F. L. Bishop: At the University of Pittsburgh this year we are attempting to grade our students on characteristics selected after a study of the methods used by different industrial concerns. The Westinghouse Electric and Manufacturing Company has made a special study of such grading. After selecting the list based on the experience of the Westinghouse and other companies, our professor of psychology was asked to criticise it. After our professors had graded the students, I noticed that one had marked all of the students "A," while another had marked all of the members of the same class "B." When the latter was asked if the carbuncle he had on the back of his neck had anything to do with the grading he said that undoubtedly it had. The characteristics of the professors have a great deal to do with the grading. The greatest advantage of grading is that it compels each professor to study his students with a little more care. In the coöperative courses we must know something more about the student than in other courses.

Dean Anthony: Why do you confine that to coöperative work? Isn't it equally important that the principle be applied to all courses that the teacher may be compelled to make a proper study of the characteristics of all students?

Principal A. L. Williston: Professor Harding and Dean Bishop have called our attention in a striking way to the fact that many of us have suspected that we really did not know our students. There is most conclusive proof that we do not; and is there any reason to be surprised at the fact when we see the extent to which we have subdivided our work? Universities in this country have grown exclusively on departmental lines where the interest in subject matter is controlling. Interest in the individual student and in his differences from his fellow students should be a controlling feature. It seems to me the pendulum has got to swing in a direction opposite to the one in which it appears to be swinging at present. We have got to divide our students into groups, and put each group in the charge of a small enough number of men who will guide and control its members, so we shall know what the students are doing in all their activities in the university. If we can move in that direction, such marked contrasts of judgment between that of the students who know their fellows and that of the teachers, who do not, will commence to disappear.

Professor C. M. Wirick: I think that it was Oliver Wendell Holmes who said there were several kinds of boy in one. There was first the boy as he actually was, then the boy as he thought he was, etc. Now it is very important that the student's own opinion of his characteristics be taken into account. After the poor devil has been judged by a hundred other people he might be asked to judge himself. Then he might be asked to account for himself if he can, and his own estimate of himself might be kept before him. If I were a boy I should insist on the right to say something for myself before I would quit. I should like to know whether this has been provided for in these grading systems and whether the student has been allowed to express himself at all to account for his delinquency, or must he explain his success in some other words of these chums and those professors who do not know him.

Professor C. Frank Allen: A distinguished engineer from a French school made an address at Zurich, and formulated the qualification of the successful engineer. He stated the first was "character," the second was "intellect," the third "scientific foundation," the fourth "knowledge of men" and the fifth "knowledge of engineering." The elements which Dr. Kent has stated are somewhat similar. Mental caliber is a different term for intellect. Nothing appears here as a recommendation to the employer as to the scientific foundation that the student has; is it possible that this does not interest us as a society? There is nothing said in regard to knowledge of men, which some think is important. I agree with Dr. Kent in his estimate of the importance of character. If that be lacking, the man is of little account.

For a long time it has seemed to me that the training we give in mathematics and science, where the student must learn that wrong cannot bring right, has an important result. The training that we give in engineering colleges tends strongly to build up character.

Whether we can do anything to create intellect or not, is a doubtful question. You have heard that a fish diet is recommended for the development of the intellect. There was a case not long ago of a man who wanted to try it. He did so but stated that no good resulted from the experiment. It had to be explained to him then that it was never claimed that fish could create intellect, but it was claimed that fish would develop it.

"Knowledge of men" was the subject of a paper before this society a number of years ago by a prominent educator. In the paper he claimed that the attention of students should be called, before they are through with their school work, to the fact that they should study men systematically; and a slight impulse in that direction will do much for them.

I could not help thinking, in taking into account the elaborateness of the system under discussion, that there was a large amount of energy expended in the use of the yard stick. I take that as a serious defect of many teachers, the spending of more time on a marking system than on curing defects. I wondered whether the money expended here was spent in the right direction.

I was somewhat surprised to learn that unless one is engaged in coöperative education, it is a fallacy for him to believe that he can know anything of his students. From force of circumstances, for two years past I have spent seven weeks each year in the summer survey camp, dressed in a khaki suit, sitting at the same table with the student, working with them, associating in some way with a number of them every day from 7 in the morning until 10 at night. It is a shock to me to learn that my time was wasted as far as gaining any knowledge of students is concerned.

Professor A. M. Wilson: The statement of Professor Allen is hardly fair to the coöperative system. The statement of Dean Bishop simply meant that if a teacher is in touch with an employer of his students, he is in a good position to know more about those students than he possibly could under the usual school conditions.

STUDENT CHARACTER AND PERSONALITY RECORDS.*

BY W. M. RIGGS,

President of the Clemson Agricultural College of South Carolina.

How often do college presidents and other college officials receive letters like this?

> *Dear Sir:* Mr. John Doe, once a student of your college, is applying for a responsible position with this company. Will you kindly give us a frank expression of opinion as to the character, disposition and ability of the applicant? Your anticipated reply, for which in advance accept our thanks, will be held in strict confidence.
>
> Yours very truly, etc.

I find upon investigation that John Doe graduated seven years ago. I did not know him personally. I do not know who were his teachers, and if I did, it would be to find that many of them are no longer at the college. Time has dimmed the memory of those who remain. I find his grades in the office records. He was an average student, that is about all I can find out about him.

THE STUDENT'S RIGHTS.

Every student has a right to count as a business asset of no small value, the recommendations to which his life and work at college entitle him. But upon what shall I base an opinion of his character, disposition, energy, leadership, personal appearance, and those other qualities which mean more than do grades to my inquirer, and to the former student who has referred his prospective employer to me? At most, a grade is but a measure of brains and application combined;

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* Presented at Nov. 1913 meeting of the Association of American Agricultural Colleges and Experiment Stations.

a sort of mental foot-pound as it were. But a foot-pound is not a suitable measure of volume or speed. And so a grade is not an appropriate scale by which to measure a student's personal or character qualifications.

How, then, shall we manage to embalm and keep handy the consensus of opinion of his teachers regarding those vital traits of character and disposition which are the factors of one side of an equation, the other side of which is expressed in terms of success or failure?

A Practical Record System.

The difficulty and embarrassment experienced by the writer led him to devise a system of recording estimates of those qualities which in the business world are put above mere class grades. The general method was first suggested by a system used in its Schenectady works, by the General Electric Company, for keeping up with the progress and worth of student apprentices. Their system, while radically different from ours because having a different end in view, suggested the application of like principles to college uses.

In brief, our method is as follows:

At the end of each session, teachers are asked to give opinions concerning the students who have come under their instruction for a sufficient length of time to enable them to form a just opinion. An estimate under each of the following headings is asked for all students:

Character, disposition, native ability, earnestness, promptness, accuracy, energy, gentility, personal appearance and neatness, class standing, preparedness; (juniors and seniors) technical ability, leadership.

When the system was first inaugurated three years ago, numerals from *1* to *4* were used to express these opinions, *2* representing fair or average standing; *1*, excellence above the aevrage; *3*, rating somewhat below average, and *4*, practical worthlessness.

However, this system of recording proved rather unsatisfactory, because the symbols used were all too familiar as applied to other purposes. An instructor could not make himself think in terms of "*2*" as a satisfactory standard.

After considerable thought, a set of symbols was adopted not so closely associated with the class-room. They are explained below:

THIS REPORT is to be forwarded through your Director with your
Third Term Grades

INSTRUCTOR'S CONFIDENTIAL REPORT

For Session Ending June 9, 1914

................*Senior*................CLASS, Section................*2*................

NAMES	Reputation for Character	Disposition	Native Ability	Earnestness	Promptness	Accuracy	Gentility (manners)	Personal Appearance	Class Standing	Energy	Preparedness*	Technical Ability**	Leadership**
Doe, J..................	e	e	s	s	s	s	e	s	m	s		m	e
Long, W. D..	m	b	b	b	d	d	m	s	b	b		b	b
Manly, E. N............	e	s	e	e	e	s	e	e	s	e		e	s
Tell, M. E...............	m	m	m	s	s	m	m	m	m	m		b	m
Smith, O. P.	e	e	s	s	s	e	s	e	s	e		e	e

USE THE FOLLOWING SYMBOLS:

e—Conspicuous for excellence.
s—Above the average, superior.
m—Of quality to attract no special attention one way or the other, medium, average.
b—Below average, inferior.
d—Conspicuously deficent.

* Answer only for Freshmen. ** Answer only for Juniors and Seniors.

NOTE:—Instructor's name will not appear on the permanent record.

Respectfully submitted,
............*W. W. Wright*........, Instructor.

The teacher's report is made on a prescribed form (see next page), columns being provided for the names and the estimates under each heading.

In order to insure candor of expression, the instructors are given to understand that their opinions will not involve them in any personal responsibility. It is the combined opinion, not any one individual opinion, that counts. Instructors are urged to give sufficient attention to the students during the session to insure reasonably accurate and just opinions.

The grades as taken from the teachers' reports, are posted on a card. A small picture of the student cut from a group picture is mounted in the lower right-hand corner.

Name *Doe, J.* Height *5'–8"* Weight *140* Type *Blond*

Character	Fresh.	e	e	e	e	e	e	
	Soph.	e	e	e	e	e	e	s
	Junior	e	e	e	e	e	e	
	Senior	e	e	e	e	e	e	s
Disposition	Fresh.	e	e	e	e	e	e	
	Soph.	e	e	e	e	s	s	s
	Junior	e	s	e	e	e	e	
	Senior	e	s	e	e	s	e	e
Native Ability	Fresh.	s	e	m	s	s	m	
	Soph.	s	s	e	s	m	e	m
	Junior	m	s	s	e	s	s	
	Senior	s	s	e	e	e	m	
Earnestness	Fresh.	e	e	s	s	e	s	
	Soph.	s	s	e	s	s	e	
	Junior	e	e	e	s	s	s	
	Senior	s	s	m	s	s	m	
Promptness	Fresh.	e	e	s	s	s	s	
	Soph.	s	s	e	s	e	s	
	Junior	e	m	e	e	m	s	m
	Senior	s	s	s	e	s	s	
Accuracy	Fresh.	e	e	s	s	e	m	
	Soph.	s	s	e	s	s	e	m
	Junior	e	s	e	e	s	s	
	Senior	s	e	m	e	e	e	

Gentility (Manners)	Fresh.	s	e	s	s	s	s
	Soph.	s	s	s	s	e	s
	Junior	e	s	m	e	s	s
	Senior	e	s	s	s	m	e
Personal Neatness and Appearance	Fresh.	s	s	s	m	m	m
	Soph.	m	e	s	m	s	m
	Junior	s	m	s	m	m	s
	Senior	s	s	s	e	m	m
Class Standing	Fresh.	e	e	s	s	s	m
	Soph.	s	s	e	s	m	e
	Junior	s	s	s	s	s	m
	Sehior	m	e	s	s	e	e
Energy	Fresh.	e	s	s	s	e	s
	Soph.	s	s	e	s	m	e
	Junior	e	e	s	s	e	s
	Senior	s	m	e	e	m	s
Demerits	Fresh.						
	Soph.						
	Junior						
	Senior						
Prep'ness	Fresh.	s	s	m	m	m	m
Tech. Ability	Junior	s	m	e	e	s	m
	Senior	m	s	e	s	e	s
Leadership	Junior	s	s	s	e	s	s
	Senior	e	s	s	s	s	e

Parent or Guar.......H. A. Doe..... Home Adr's.......Columbia, S. C.....

R. F. D. or Street Address...................2000 Sumter St....................

Entered Col...........1908..........; at Age ....17....; Left Col.........1912......

Cause of Leaving...............................Graduation..............................

Remarks : ....

Course..........................Agricultural...........................Scholarship Student

Key to Symbols: e — Conspicuous for excellence. s — Above the average. m — Of quality to attract no special attention one way or the other; medium, average. b — Below average, inferior. d — Conspicuously deficient.

The cards contain also information as to the weight, height, age, type, home address, date of entering and leaving college, cause of leaving, etc. On the reverse side of the card the student's practical experience before coming to college is recorded.

At the end of each session, a student will get from his teachers from eight to fifteen opinions. By the time he graduates, he will have recorded from thirty to sixty opinions as to his character, disposition, energy, promptness, earnestness, etc.

The Plan in Operation.

My observation is that the record for any particular student, though marred occasionally by a "man eater" or by some opinionless fellow, is generally quite consistent. Like the "shot-gun diagram" obtained in testing incandescent lamps, the cards show the *consensus of opinion.*

If you have ever known him, the photograph recalls the student to your mind, and you have before you his age, the duration of his stay in college, the course he took, why and when he left, and all other information desirable in writing a recommendation. Whenever my secretary sends to my desk a request for an endorsement, he always attaches to the letter the confidential record card which the student has left behind him.

Not only is the record valuable as a ready reference. The student is kept reminded that day by day he is making this record; that opinions are being recorded which, if not creditable, may rise up to plague him in years to come. Such knowledge is no inconsiderable spur to better work and better conduct. A knowledge on the part of the instructors that they must be prepared to give accurate opinions at the end of the session should stimulate an interested study of the individual student.

Imperfection of the System.

The system is open to some serious objections. It is offered merely as an imperfect attempt to meet a real difficulty.

In the first place, it is often difficult for a teacher to give accurate opinions if his classes are large and his hours limited. As a result, the card is likely to be partial to the student, for a teacher like a baseball umpire, when in doubt, usually and properly gives the benefit of the doubt "to the runner." Then too, in that strange collection, a college faculty, there will always be found a small percentage of reactionaries, who oppose any new idea and refuse to give more than perfunctory coöperation, whereas to be of value, a large amount of painstaking, conscientious labor must go into the job of making the records, which are turned in at the end of the session.

Four years of experience has convinced me of the utility of these confidential character records. They are constantly consulted not only by the president, but by other officers of the college who have appointments to make, or recommendations to write. Almost invariably they can be depended upon to give to the student more than justice, and to the officer seeking information, a dependable basis for an opinion. The records show, in concrete form, the consensus of judgment of those best qualified by opportunity to judge the student.

I commend this system of student character records to colleges having at present only the class grades, in whose insufficient light to judge of those other and transcendant qualities which go to make up a man who is greater perhaps in every other respect than in mere scholarship.

BETTER ENGINEERING TEXT-BOOKS.

BY F. H. SIBLEY,

Associate Professor of Mechanical Engineering, University of Kansas.

The critics of engineering education have generally directed their criticism at incorrect methods and incompetent teachers, while poorly written and illy adapted text-books have been ignored as a factor in the so-called failure of technical-school training.

If the relatively great amount of time which students are expected to spend in the study of books is to be profitably spent the books should be so written and arranged as to demand the minimum of time and effort in the reading. That the maximum of time and effort is demanded is apt to be the case.

Good books are harder to find than competent engineers or successful teachers because the literature of the profession has lagged behind professional attainment. The reason for this may be found in the fact that successful practitioners are not always trained for writing books and the quality, if not the quantity, of the books that have been written indicates that success in one line does not necessarily mean success in the other. Then too, technical writing has been regarded much as a " yellow dog," and since it seldom pays either in money or reputation the engineer who is competent to write a book must do it as a matter of professional interest or duty.

SOME TEXT-BOOK FAULTS.

There are certain faults in the books that are so glaringly evident that one need not be a literary critic to point them out. Prominent among these is the misuse of symbols and formulas. In books that contain mathematical demonstrations it is not uncommon to find ideas stated symbolically when plain English would have answered the purpose better.

When the same symbol is used to represent more than one thing or its meaning not stated in close proximity to where it is used, exasperation is added to the other troubles of the reader. The labor of reading and comparing several texts would be greatly diminished if there could be some recognized standard for the meaning of symbols.

In the derivation of formulas gaps are frequently left between one form of an equation and another without any explanation of the intermediate steps. Here is an example:

An expression for the derivative dp/dt is obtained by differentiating the equation,

$$\text{Log } P = \log k - n \log \frac{T}{T - b}.$$

Thus,

$$\frac{dp}{dt} = np \left(\frac{1}{T - b} - \frac{1}{T} \right) = \frac{nbp}{T(T - b)}.$$

Such condensed mathematical processes are out of place in a text-book where instead of being an aid to the understanding of the subject, they are a hindrance.

Another fault results from carelessness in the use of certain classes of words. Among these are common English words like those mentioned in President Alderson's articles in the BULLETIN of February and March, 1913, entitled "Miscellaneous Faulty Expressions." This list might profitably be extended by publishing the complete compilation which the author mentions in the footnote.

Familiar words used in an unfamiliar sense and unfamiliar technical words are two other classes that are likely to give trouble to the student. The dictionary will not always help even with the first-named class and as to the second. almost every species of animal and household appliance has a technical counterpart that the dictionaries do not mention at all. What is true of standardizing symbols applies with equal force to the advantage of standardizing words of these two classes and this work can be undertaken none too soon.

The use of the words "former" and "latter" should also be mentioned as examples in this connection. These are handy expressions when properly used but when they are separated by several sentences from their antecedents, they add enormously to the labor of the reader.

A third fault is that of giving so much detail either in the form of unnecessary words, phases or material that the reader is bewildered and loses sight of the fundamental ideas. The following example is a good illustration of the "long-winded" style that results from using too many words:

"The total ratio being settled on, and that allowable, as a maximum, for the single cylinder, it becomes easy to determine the best number of cylinders in series. The first mentioned ratio is that of maximum commercial efficiency, as just stated; but the second must be taken as that which gives the highest efficiency of engine, the back pressure in that cylinder and its friction, taken singly, being considered, together with its proper proportion of the friction of the engine as a whole."

The technical student ought to be, and generally is, too busy to waste time in sifting such abstruse paragraphs as this. Some pretend to think that such reading furnishes good training of the perceptive faculty but if the student gets any training at all from it, it is likely to be at the expense of his moral character and besides it is better to acquire mental training by *mastering* principles rather than by *digging them out* from a mass of obscure English.

Equally annoying to the reader are such hackneyed and foolish expressions as "It is evident," "As everybody knows," "It therefore follows." These statements are apt to precede, humorously enough, a wordy explanation of the evident thing which everybody knows, or is supposed to know.

Unnecessary material in the form of historical, reminiscent and amplifying paragraphs would nearly always be better left out. For example, how many books on the subject of heat engines begin with a description and illustration of Hero's engine? This is useless "lumber" and nearly always fills the place of something the book should but does not contain.

Perhaps the worst fault of all, as well as the most common. is that of poor arrangement. Poor in the handling of detail and poor in the sequence of chapters or divisions of the subject.

In the matter of detail, the confusion of ideas that results from a bad arrangement of sentences and paragraphs is familiar to most readers. In this respect many of the books are little more than a heterogeneous collection of facts wherein not only are the principles. which the author is trying to set forth, obscured but the facts themselves are made unavailable. Who has not turned over and over the pages of some well-known book in search of information that ought to be in a certain place and found it at last tucked away in an obscure sentence of an unimportant-looking paragraph?

Careless chapter planning results in illogical treatment of the subject, which is impossible for a class to follow. That this is not an imaginary failing is shown by the following illustration taken from "The Steam Engine."

TABLE OF CONTENTS.

I.	Introduction.
II.	Commonest Form of the Steam Engine. (Includes a discussion of the Gas Engine and the Steam Turbine.)
III.	Value of Expansion.
IV.	The Indicator.
V.	The Reciprocating Motion.
VI.	How the Valve Acts.
VII.	Valve Gears.
VIII.	The Exhaust and Feed.
IX.	Flywheel and Governor.
X to XIV.	*Steam Boilers.*
XV to XVII.	Thermodynamics.
XVIII.	Properties of Steam.
XIX.	Properties of Gaseous Fluids.
XX.	Entropy.
XXI.	Water, Steam, ϕ Diagram.
XXII.	Cylinder Condensation.
XXIII.	*Combustion and Fuel.*
XXIV.	*Boiler Efficiency.*
XXV.	*Gas and Oil Engines.*
XXVI.	Valve Motions.

XXVII.	Inertia of the Moving Parts.
XXVIII.	Kinetic Theory of Gases.
XXIX.	Thermodynamics.
XXX.	Superheated Steam.
XXXI.	How Fluids Give Up Heat and Momentum.
XXXII.	*Jets of Fluid.*
XXXIII.	Cylinder Condensation.

The faults indicated, as well as many others that might be mentioned, all contribute to a literary style that results in the student acquiring incomplete and erroneous notions. slipshod methods of reading and repugnance to all study of books.

How Books Might be Improved.

That a good literary style is possible in dealing with even the most technical subject was well illustrated in a recent issue of one of the non-technical magazines. It contained an article by an experienced writer, on the Diesel motor. Only one or two short paragraphs were given to the description of the motor itself yet it was handled in such a way that even a non-technical reader could not fail to understand the principle of the machine and how it differed from the automobile engine with which it was contrasted. Not only this but the article was delightful reading. A description covering the same ground, in the ragged, obscure and jumbled up style of some of the engineering text-books, would have filled pages, made the driest of reading and would have been unintelligible to any but the initiated.

Aside from literary considerations there are certain practical aspects in which both the appearance and usefulness of the books might be improved. Among these is a complete cross index. Scarcely two people will look up a subject in the same way and unless the index is carefully planned the book is of little use as a reference.

Lettered sketches should be kept close to the text which refers to them. The interruption caused by turning back or forward to a reference sketch is burdensome, especially where the same letter in the capital and lower case form is used.

Sketches should be simple; they should contain all of the lines and symbols referred to in the text but no more. This seems almost too self-evident to need mention, yet it is astonishing how often it is unheeded.

The appearance and convenience of books would be improved if all publishers would follow the example already set by some and adopt one or two standard sizes instead of the half dozen sizes that are now common. There seems to be no good reason why there should be more than two, the pocketbook and the six-by-nine sizes.

While undoubtedly books have been improved very much in the last few years it is pertinent to ask what, if anything, can be done to accelerate the process. To point out the faults is easier than to suggest a feasible remedy. It is not probable that there is any panacea, books will continue to improve gradually in the future as they have in the past but those who recognize the need of improvement will probably admit the truth of the following general propositions:

Writers should be trained for this particular work, they should do research work in sifting and compiling available material and arranging it with the student's point-of-view always in mind and with an intimate knowledge of his needs.

More constructive criticism is needed of books before they are published. The detail plans of any important engineering structure are checked and re-checked and a text-book is a sufficiently important work to demand the same treatment. No writer, however wise he may be, is likely to produce a very good book without the help of such criticism, and any author, especially a young one, who takes the position with the publisher that his book must be printed as written or not at all, is foolish to say the least.

Books should bring better compensation to authors and publishers, something which would take place automatically with increased sales. Increased sales would also result in better later editions and decreased cost to the purchaser. Paying several times what a book is worth is a real burden to many students and one which should be eliminated.

A Comprehensive Text-Book Committee Needed.

The question now arises, What can be done to bring about these results? As one suggestion, a joint text-book committee might be appointed by the engineering societies and the publishing houses whose duty it would be to aid and encourage the production of better books. While to specify the duties of such a committee beforehand would not be easy, the following suggestions would seem to be practical and if the committee were once organized, its activities would undoubtedly be broadened and better defined.

It could support the publishers in many cases in insisting upon rigid criticism by competent authority, before the publication of a book. It could not, of course, take under consideration all of the great number of books that are offered nor would it need to do so but only those that had been accepted for publication.

The members of the committee might encourage writers of promise or of proved ability by using their influence with college authorities to have other duties made lighter so as to give more time for writing.

The committee might publish an authoritative book review and perhaps recommend certain books for certain courses. This recommendation would be an aid to teachers in selecting a text and presumably it would encourage broader use of the best ones and discourage unnecessary duplication.

It could help to carry on the work, already started, of standardizing words and perhaps do something towards standardizing symbols. It might also consider the matter of uniform sizes of books.

To carry out all or any one of these suggestions in detail would be no small task and perhaps no committee could be expected to do gratuitously all of the great amount of work indicated, but the simple fact of the existence of a committee known to be working for the improvement of the books, would of itself be a tremendous force in this direction.

A REPORT OF PROGRESS IN COÖPERATIVE EDUCATION.

BY A. M. WILSON,

Professor of Electrical Engineering, The University of Cincinnati.

About twelve years ago, very few educators had even heard of what is now called coöperative education. They may have run across some casual mention of the principle involved, by ancient or mediaeval writers on the subject. But as none of these statements was the result of a carefully devised plan to meet an apparent need of the civilization of the time; they evidently failed to produce any result.

When Herman Schneider worked out the plans for what he has called the coöperative system of education, and presented them for the consideration of several manufacturers, as a means for developing the trained men they needed, many of those who had occasion to consider them were strongly impressed. The advantages of the scheme were obvious. But it was such a radical departure from educational practice, that no manufacturer could be prevailed upon to give it a trial. While the ordinary form of technical education was of comparatively recent development, it seemed to be hoary with tradition when compared with Schneider's proposition that students should learn the practice of any trade or science by practicing it. And it is possible that teachers were not enthusiastic in recommending or approving a system of education which obviously involved more effort on their part.

Even now, there are those who do not appreciate what this new departure in education means. It is not the province of this article to go into a discussion of the ideals from which the practical ideas of the coöperative system developed. Possibly there is no better way to arouse interest in it, than to tell what has been accomplished in one field only. For the ideals themselves include possibilities which would probably seem, to the conservative mind, as far beyond the present achievement, as it is beyond the older educational methods.

Early Problems of Coöperative Instruction.

Possibly the most striking thing about the coöperative system as applied to engineering education, and as it may be applied in any other field of human endeavor, is that it is a business proposition which appeals to the manufacturer or operator who needs trained men. It will not do to infer that all manufacturers and operators clamor for it the instant it is presented to them superficially. Sometimes it seems that the art of persuasive speech has to be developed to a very high degree, to secure the consent of some business men to a proposition which cannot fail to benefit them directly. But it was realized from the first, that the success of such a system would have to depend entirely upon its ability to meet commercial conditions at least as well as any other educational system. As in all new developments, there were many details to be changed, to meet unforeseen emergencies and changing conditions. For instance, when the course was started, the students in the school and in the shops alternated weekly; that is, one student would be at work for a week while his alternate attended the university. Recently this alternation of school and shop has been put on a bi-weekly basis. And it is proposed to make a still more marked change to suit the conditions peculiar to the civil engineering course. But the coöperative system of education has lived for eight years. It has passed the purely formative or probationary period, and now stands upon a clearly outlined commercial basis, offering an opportunity for education which seems to meet the educational needs of the democracy.

In 1906, Dean Schneider, who was then teaching in the civil engineering department of the University of Cincinnati, was given an opportuntiy to try his scheme. In a way, the situation was favorable. Possibly it is interesting to note that he, a civil engineer, made the application to mechanical engineering first. At that time there was almost no connection between the engineering departments of the university and the large and growing engineering interests of the community. So far as the university was concerned, very little could be lost by the failure of the scheme. And failure was freely predicted.

There was the usual inertia of ultra conservatism to be overcome, and there are many interesting stories, which might be told, of the difficulties which Schneider encountered. He had not only to persuade manufacturers to enter into coöperation with the university; but he had to persuade students to enter this new educational scheme. But the obvious economic advantages were sufficient to attract the necessary number of students to make a start.

The Appeal of Coöperative Training.

The appeal made to these first students has not been changed since. It contains the basic principle underlying the coöperative scheme of education. It merely states that, in a democracy, the only limit to educational advancement should be the lack of ability on the part of the student. It should be, as nearly as possible, independent of financial and social conditions. There should be no "royal road" in any sense. An ambitious mechanic, living in Cincinnati, who has a son sufficiently talented to acquire a college education, may, through the coöperative system, give him such an education without bearing a heavy financial burden. A student's earnings will be sufficient, right from the start, to pay all the necessary fees, buy all the necessary books and other equipment, and clothes, and to pay more and more towards the other living expenses as his value as a producer increases.

While the first appeal was most effective with those to whom the financial problem was a serious one, the educational advantages seem to be appealing more and more strongly to those to whom the financial problem is not so serious. It is interesting to note that a very large percentage of applications for entrance into the college comes from well-to-do youths who are anxious to put themselves to the test of actual service. It would seem that this in itself must be a decided advantage.

Eight Years' Growth.

For the first two or three years, the growth was not phenomenal. But the advantages both to the students and to the business interests employing them soon began to be appreciated, and the demand for enrollment in the engineering courses increased rapidly. During the years following the 1907 panic, when the enrollment in other engineering schools decreased to a marked extent, the attendance at the University of Cincinnati showed a healthy increase.

The enrollment in coöperative engineering for 1913–14 was practically 400. The limitations of facilities to properly care for more students permitted only one hundred and eighty freshmen to enter. There were more than three thousand inquiries. What might be called a practical test of the scheme was had during the business depression of last winter. At no time was its operation affected to an appreciable extent, although the work of those in charge of shop arrangements for the men was necessarily more difficult than usual. Even if the depression had been so severe as to necessitate the closing down of all the shops in the city, that would not have indicated a weakness in the coöperative principle. But time and space will not permit of a proper discussion of this phase of the question.

Incidental But Essential Educational Features.

It has been necessary, in operating the coöperative courses, to consider education from many new view points. One of the important matters demanding practical solution was the problem of getting the right man in the right job. This did not provide a field for the vocational guidance expert of the type which seems to have fallen into some disrepute recently. Dean Schneider has made an interesting attempt to put men into work for which they are best suited. To do this effectively an extended series of observations has been carried on. Some of these observations have been made by instructors, some by shop foremen, and some by the department of psychology. When sufficient work has been done to warrant it, there should be material for a rather interesting paper along this line.

Another feature connected with the coöperative work is the analysis of the courses of study, to adapt them to the needs of the men. It is quite apparent that such a radical change in educational methods would necessarily involve considerable change in the arrangement of curricula. It may be stated, that we have just recently reached the point where no further change of a pronounced character is anticipated.

From the study of the curricula and the necessity for keeping records of the students in shop and school, the faculty room has developed into a sort of educational laboratory. From the fact that freshmen needed some sort of elementary instruction regarding their jobs, to work efficiently, a rather elaborate system of syllabi is being worked out, not only for the shop work, for the benefit of the students, but for the class work, largely for the benefit of the faculty. The study of object, method, matter and mechanism connected with the work of the students, suggested corresponding studies in connection with the various subjects of the curricula. These syllabi of class work will serve to systematize the pedagogical work of the faculty to a much greater extent than would be possible under the usual methods of more restricted discussion of such subjects.

Relative Cost of Coöperative Teaching.

As in the case of nearly every other new departure in the field of human endeavor, the claim is made by its sponsors, that not only is higher educational efficiency obtained, but that this is accomplished at lower cost to the community. It is understood that it is hard to estimate values in such work as education: but there should be limits to such concrete values as the amount per student per year, which is not paid directly by the student.

If we confine ourselves to the intangible values, we are at once confronted with the fact that, in addition to actual experience in productive work, the coöperative student gets whatever value there may be in the technical and cultural studies offered at the University of Cincinnati, while he is in direct contact with the problems of capital and labor, and the conditions under which large numbers of men earn their living and live their lives. The fact that summer employment is encouraged by all technical schools indicates that these values are appreciated. But this summer employment is carried on usually in a hopelessly desultory fashion with no responsibility on the parts of either the faculties or the students. There should be more of this intangible value in such systematized practical experience as is offered in the coöperative courses, than can possibly exist under the usual lack of system.

Regarding the values as expressed directly in money cost, the time available for this article did not permit a careful scrutiny of the financial statements of institutions, so that the various items involved in education might be properly charged. It is probably not far wrong to say, that it would be a very difficult task to apportion the cost of education properly among the various departments, even if the financial statements of many institutions were available. A superficial study of such data from about twenty-five institutions of higher learning indicates that the average cost per student per year, on the basis of gross income, varies from about $600 to about $170. This, of course, does not include any percentage of the investment in buildings, land and other necessary equipment which has cost money. The average of the above values of cost per student per year, by institutions, amounts to about $320, not including percentage of lands, buildings and equipment. To find the apparent average net cost per student per year, the proper amount should be added to cover the cost of land, buildings and equipment, and from the result should be subtracted the amounts paid by the student as tuition and other fees. It might be stated that some of the institutions considered maintain both medical and engineering schools, and some do not. The gross cost per student seems to be independent of such conditions to quite a marked degree. In finding the average apparent net cost per student per year it will not be safe to take the values of tuitions and other fees given in many catalogues. In some colleges at least there seem to be so many reasons for remitting fees that a comparatively small number of students pay them. At the University of Cincinnati the average cost per student per year on the basis of gross income is about $170. The average apparent net cost per student per year, after the additions and subtractions mentioned above have been made, is about $135. In considering even this comparatively small amount, it should be borne in mind that the students return directly to the community which supports the university, through their living and other expenses, sufficient revenue to largely, if not entirely, offset this investment. This latter condition cannot be true in the case of those institutions whose funds come from a comparatively large territory.

Gains Made in Eight Years.

Another effect of the coöperative courses upon the engineering faculty is due to the necessity for a careful study of the manufacturing and operating conditions around Cincinnati. It has been necessary, in planning prospective courses, to look over the community, to see what opportunities there may be for practical coöperation. Doubtless, in the future, it will be necessary to secure accurate data along these lines. As a matter of fact, these data will probably be accumulated in the natural course of events.

During the past eight years, the number of students enrolled has increased from a dozen or so to 400. The number of coöperating concerns has increased from two or three to more than sixty, including the engineering department of the city of Cincinnati, two steam railroads, two electric railways, and a wide range of manufacturing and operating companies.

This broadening of the activities of the engineering college has in itself brought up problems in connection with the coöperating concerns which have involved additional time and labor on the part of the faculty. For instance, coöperating concerns are invited to use the facilities of the university to a reasonable extent, through their students. In this way, many interesting problems come up for solution which are of some value to the business interests of the community.

It may be of interest to note that the coöperative principle is being given more and more recognition of a very effective character. About twenty institutions of different types throughout the country have adopted this principle. So far as is known, all are meeting with success. Those in charge of such courses have to bear a little more responsibility than is involved in the older educational methods. But it does not take more than human intelligence to deal with other human beings in any business proposition. And all that is involved in the coöperative principle, is a combination of business and education in an attempt to approach more closely the ideal in education;—that every one capable of receiving an education may do so, regardless of his immediate financial and social condition; but that he be as little of a burden to the community as possible while receiving it.

Discussion.

Professor Wilson: Supplementing my paper, I may say that, in our analysis of the students to meet the situation discussed in Professor Harding's paper, we have adopted a different procedure. We have tried to work in harmony with what seems to be the methods adopted by psychologists. But our results have been worthless.

For instance, the department of psychology at the University of Cincinnati made systematic test of the students covering a whole year. Towards the end of that year, the entire engineering faculty met with the department of psychology and the ground covered was reviewed. So far as the engineering college was concerned the opinion was unanimous that no conclusions regarding the personalities of the men or their fitness for any particular type of occupation could be drawn from the results of the investigation.

It seems as though the same objection applies to the results of Professor Harding's investigation.

We have found that the only effective tests we can make are the tests which are applied to engineering graduates—the test of getting results. This is one great advantage of the coöperative system. If a student gives unsatisfactory service in the shop, his case is studied carefully. Sometimes by simply changing him from one department to another, his efficiency is much increased, and he is made much happier. These changes are made much more quickly than could be possible for the average engineering graduate. This eliminates an appreciable economic waste.

Regarding the study of the curricula of the engineering college of the University of Cincinnati, Dean Schneider has attempted to develop a suggestion he received from the National Cash Register Co. of Dayton, Ohio. Mr. Patterson, the president of that concern, requires that all subjects be presented to him in tabular, skeleton form, divided under five headings.

This chart, which should be self-explanatory, has not received the official approval of the engineering faculty. But it has been discussed sufficiently in faculty meetings, so that it may be taken as representing what we are trying to do. The final form adopted as standard may be quite different from the form of the chart shown.

One obvious advantage of a chart of this type is, that each instructor may have exact information regarding what is being done in other departments and in the classes of his own department.

Also, the development of these charts is of direct personal benefit to the individual developing them. It is expected that the details of each course will follow and be attached to the chart.

ELEMENTS OF ENGINEERING FOR ELECTRICAL ENGINEERING FRESHMAN.

Object	Method	Matter	Mechanism	Prerequisites
or instructor (1) To estimate the students as to (*a*) training, (*b*) mental initiative, (*c*) energy, (*d*) disposition. For students (1) The application of mathematics to engineering. (2) Knowledge of the fundamental relations between force and motion. (3) Methods of analysis of engineering data.	Class room work. Chiefly recitations with individual blackboard work. Occasional lectures. No text-book was used in 1913-14. Specific problems were assigned, and used as a basis for discussion, with occasional mimeographed notes. Quizzes at definite intervals.	Newton's three laws. Problems on bodies at rest under concurrent external forces. Problems on linear motion with constant acceleration. Typical examples. Two men pulling on a rope. The tilting of a box. The forces on a simple beam, a step ladder, a jib crane, etc.	3 hrs. a week during the school weeks of the first semester. ½ hour each week for a quiz. 3 hrs. a week during the 8 school weeks of the second semester. ½ hr. each week for a quiz. 6 hrs. each week during the 5 school weeks of the summer term. During the last two weeks of the summer term, daily half hour quizzes are given covering the entire year's work. Total hours during the year = 78.	During the first two weeks the prerequisites are algebra, three quadratics, logarithm, plane geometry. After the first two weeks trigonometry is added.

There is a limit to which the instructor may enter into the individual life of a student, particularly where the classes are large. The freshman classes are usually large. Last year we started with 180 freshman. Each instructor and many of the shop foremen and superintendents were furnished with the accompanying blank form, which they filled out. This was found to be of considerable practical value, as compared with the standard psychological tests. The task of keeping such records may be too great to justify them.

Forms filled out for each student in 1913–14.

Name....................................

a. Physical strength
Physical weakness
b. Mental
Manual
c. Settled
Roving
d. Indoor
Outdoor
e. Directive
Dependent
f. Original (creative)
Imitative
g. Small scope
Large scope
h. Adaptable Social
Self-centered
i. Deliberate
Impulsive
j. Music sense
k. Color sense
l. Manual accuracy
Manual inaccuracy
m. Mental accuracy Logic
Mental inaccuracy
n. Rapid mental co-ordination
Slow mental co-ordination
o. Concentration (Centripetal, mental power)
Diffusion (Centrifugal)
p. Dynamic
Static

We find that the majority of the students do not need much attention. Only the special cases are taken up individually by the professor in charge, or by the instructor appointed by the advisor. Cases which seem to justify it are referred to Dean Schneider. Formal record is kept of these special cases. Since our relations with shops are often involved, we are forced to give these cases closer attention than is necessary in the usual engineering course.

A DEPARTMENT OF ENGINEERING IN THE JOHNS HOPKINS UNIVERSITY.

BY JOHN B. WHITEHEAD.

Professor of Electrical Engineering, The Johns Hopkins University

The Johns Hopkins University has announced the opening of a department of engineering. This entrance of Johns Hopkins into a new field of activity has been made possible by an act of the General Assembly of the state of Maryland appropriating for the purpose a substantial sum of money for buildings and equipment and also a continuing annual income for maintenance. The laboratories are now in process of construction at Homewood, the site of the university's new home in the northern section of Baltimore, and the first undergraduate class is already in attendance.

This new move was, perhaps, received with surprise by many who are familiar with the history, aims, and past efforts of the university. The character of the educational training for the profession of engineering in this country has not generally been such as to suggest a legitimate field of effort for an institution which has limited itself almost entirely to strictly graduate or university activity. While a number of colleges and engineering schools offer graduate courses in engineering, in nearly every case these courses have been added to an undergraduate curriculum in engineering and they have not attracted many students. By far the greater number of students complete their formal professional training at the end of the undergraduate course. Harvard, for several years before the merging of its school of applied science with the Massachusetts Institute of Technology, exacted a baccalaureate degree for entrance, but in spite of its high purpose the plan did not result in marked success, and is now apparently abandoned in the coöperative merger with the Institute of Technology.

Since its inception and foundation The Johns Hopkins University has emphasized as its chief aims investigation, research and graduate training. The standing and reputation it early created for itself in this field of the pure university and which found concrete expression in its faculty of philosophy, have also been sustained in the plan and subsequent development of The Johns Hopkins University medical school. The questions may well be asked, therefore, why Johns Hopkins has undertaken work in a field which, at first sight, appears foreign to its traditions and tastes, and what influence these traditions will have upon the methods which will be adopted in its new work.

History of the Inception of the New Department.

The circumstances leading to the Act of the Legislature making possible the creation of the new department apparently began with a prospectus which was prepared about six years ago, when the university was making an appeal for financial aid in its plan to move to Homewood, the beautiful site presented by several of its friends in Baltimore. This prospectus announced several directions in which the university wished to extend its efforts after removal to its new home. A graduate school of applied science was mentioned as an especially promising field.

While the appeal for a school of applied science failed to make impression on the wealthy philanthropist, it nevertheless excited many public expressions of endorsement. It was suggested that the state of Maryland should provide means by which Johns Hopkins could create an advanced school of engineering which should offer special opportunities to the residents of Maryland. It was pointed out that inasmuch as the university had already a well-organized system of courses in the sciences and other branches preparatory to training in engineering, an excellent opportunity was open to the state to secure a school of engineering of the best type at moderate cost, if the university could be prevailed upon to undertake the responsibility. The press kept the matter constantly before the public, and sought the opinions of many prominent men, publishing them from time to time. It appeared that there was a very large sentiment in favor of the project. Among other things, attention was called to the large number of manufactures in the state requiring technical skill, to the number of men of technical training employed by railroads, public service corporations and state activities, and also to the fact that there were more than three hundred residents of Maryland pursuing courses in engineering in schools and colleges outside the state. As a result of this activity shortly after the convening of the Legislature, a bill was introduced appointing a committee of legislators to confer with the university as to the feasibility of the plan and as to the willingness of the university to assume the obligation and responsibility.

Throughout this campaign the university remained in a neutral attitude. While a number of the alumni were enthusiastic advocates of the plan, there was at first within the institution some feeling that the assuming of such a responsibility as was proposed might in some way impair its ideals and possibly lessen its prestige. However, with the appointment of the committee of the Legislature and when it became apparent that the advocates of the plan contemplated an approximately unconditional gift to the University for the creation of a school of Engineering, all doubt as to the duty of the university was quickly removed in the minds of the trustees and faculty. The committee of the Legislature was invited by the university to visit a number of schools of engineering, the value of engineering education was pointed out, and estimates were made and submitted as to the amount of money necessary for buildings and equipment and for annual maintenance. Thanks to the discrimination and broad attitude of the committee a favorable report was made to the Legislature and a bill was introduced appropriating $600,000 for buildings and equipment together with a substantial annual sum for maintenance.

Too much cannot be said for the broadminded and intelligent consideration which was given to this bill while it was before the Legislature. Naturally there was some opposition and many amendments were introduced which, had they been incorporated in the bill, would have deprived it of much of its value. As finally passed, however, it is doubtful whether a more liberal and far-sighted provision for university aid has ever been made by any state. Under the bill The Johns Hopkins University is absolutely free to conduct engineering education as it deems best. Its sole obligation is the awarding of certain scholarships carrying free tuition to the residents of various counties and legislative districts of Maryland. The legislative bill, in fact, exacts that its provisions shall in no way restrict the university in the standards which it sets for entrance, for conduct and for graduation. It stipulates that the standards to be maintained in the teaching of engineering shall be equal in all respects to those in other departments of the university. While not explicitly required and while the school is described as a school of advanced technology, it is nevertheless the obvious intent of the bill that the university shall provide courses of undergraduate instruction. In all other particulars the matter is left entirely to the university to adopt such methods as it sees fit, without scrutiny and without legislative or other suggestion. The passage of this bill is a signal tribute both to the character of the men comprising the Legislature of 1912, and also to the standing and confidence which The Johns Hopkins University enjoys in its own state.

Preliminary Survey of the Possibilities.

With the passage of the legislative bill an accomplished fact, the university authorities were confronted with a number of important questions which required answer before definite steps for creating the new department could be taken. What should be the general scope of the work to be undertaken? Should greater emphasis be given to undergraduate or to graduate instruction? Should the plan be patterned after that of existing schools of high standing or should modifications be made? What should be the relation of the new department to the existing organization of the university? Should these questions be determined before or after the initial faculty was chosen? What steps should be taken in order to put the new buildings and laboratories under construction as promptly as possible?

The university was not, however, entirely unprepared to answer questions of this nature. A number of members of the scientific section of its faculty have long been in touch with those branches of engineering most closely related to their respective subjects. In particular the departments of physics, chemistry, and geology have been identified with a number of projects involving engineering skill. It will be remembered that the late Professor Rowland was a member of the international commission which reported upon the feasibility of the utilization of the power of Niagara Falls. Since that time the university has always maintained, as part of its department of physics, graduate courses in applied electricity. Ex-President Remsen has been an active member of the State Roads Commission of Maryland, and of the Sewerage Commission of Baltimore. The Department of Geology has been actively associated with the Geological Survey of the State of Maryland, and with the work of the State Roads Commission. Professor Clark is the State Geologist, other members of the department are on the scientific staff of the commission, and Professor Reid has rendered important services in the development of improvements in road construction. Other departments of the university have also participated in undertakings of similar nature outside the university.

During the visits of the legislative and university committees to the principal engineering schools of the east, and also through correspondence with the officers of these institutions, valuable definite knowledge had been gained as to the amount of money which would be needed to start a school of engineering having three or four departments, and the probable annual cost for operation. The information so gained was the basis for the amount appropriated in the bill for these purposes. Upon the passage of the bill a committee of the faculty began a further systematic series of visits to existing schools of engineering. This series of visits extended over several months and embraced practically every engineering school of importance east of the Mississippi River. Also during this time a number of prominent consulting engineers were invited to Baltimore and their opinions asked as to how the efforts of the university could best be directed in its aims to provide proper education for students intending to become engineers, to offer opportunity for advanced study, and to contribute to the advancement of knowledge in engineering and applied science. A number of presidents of manufacturing companies were also consulted in person and by correspondence as to their experience with graduates in engineering, and their ideas as to how the shortcomings of these graduates could best be corrected.

Faults of Engineering Courses in General.

It became evident very early in these visits and conferences that engineering education in this country is not on a satisfactory basis. All four of the national engineering societies have committees on engineering education, and the Society for the Promotion of Engineering Education has existed for a number of years. The literature which is produced by these bodies, and that by independent and generally complaining commentators, is replete with suggested modifications and plans for removing the existing imperfections.

It seems to be generally admitted that the present schools of engineering, with, in many cases most elaborate equipment, are failing to turn out graduates properly equipped to meet the needs of the manufacturing and other engineering organizations which they enter. The field now represented by any one of the particular branches of engineering, is so wide that the attempt to cover it in the usual undergraduate course has resulted in the continuous introduction of new subjects, the shortening of the time allotted to others and a tendency to sacrifice instruction in fundamental subjects in order to include the study of new applications in the respective branches of engineering. It is not unusual, for example, to find ten subjects taught in a term of one half year, some of these being, therefore, limited to one hour of instruction per week. In these schools special engineering instruction begins either in the first or second year, and little or no attention is paid to the fundamental and general subjects thereafter. The usual result is that the average engineering graduate is wanting in general education, in powers of expression, in imagination and ability to reason. As possible offsets to these deficiencies, he has had a survey of numerous special engineering methods and applications, with many of which he may never afterwards come in contact, and has spent much time in courses in shop work, manual training and the testing of machinery and materials.

An excellent summary of the imperfections mentioned has been given by Professor C. H. Benjamin, dean of the engineering schools of Purdue University, who made an attempt to secure the subsequent history of 3,700 graduates in engineering. He sought particularly opinions as to their fitness for professional work and suggestions as to how educational training could be altered with promise of improvement. He received some form of statement in connection with 3,500 names. Among the replies were those of a number of employers of engineering graduates. Stated briefly the general conclusion from this investigation was that the graduate lacks practical experience, has little knowledge of commerce, business methods and economics, and must devote himself in some way to acquiring further information and knowledge of affairs for several years; that he will accomplish the above more readily if in college he has applied himself to fundamental sciences and avoided too great specialization; that the literary side of his education has been too much neglected; and that the graduate is frequently unable to express himself properly in either writing or speaking.

Among the educators, engineers, employers and others consulted by The Johns Hopkins University, there was general recognition of the imperfections which have been mentioned. Particularly widespread were the complaints of too great insistence on professional training to the sacrifice of fundamental and cultural studies. The committee carrying out the study has repeatedly asked of educators why attempt has not already been made in the way of correction. There have been two answers: first, that by certain schools the only remedy is thought to lie in the institution of five or six-year courses, thus providing the additional time necessary for the pursuit of both the cultural and professional studies; and second, that in many cases there is enough inertia in the established curriculum and surrounding tradition to make difficult any radical change in an existing course.

There are manifest advantages in terminating an undergraduate course of instruction at the end of four years. This is an almost universal custom, whether in the college of arts and sciences, or in the school of engineering: and it offers a convenient point of separation into business life, profession, or more serious study. Certainly more ground can be covered in five and more still in six years. But are five years enough for both cultural and professional training? And if six, is it not more logical, to offer a baccalaureate degree at the end of four years followed by a professional degree after two more? This plan offers a convenient stopping point for those not qualified for further rigid professional study, and may nevertheless provide good preparation in the four years for many subordinate engineering positions. As regards the difficulty of changing established practice and tradition, there is obviously no reason why the curriculum of a new school should not be so shaped as to embody as many new features as seem advisable in the light of competent criticism of present methods.

General Considerations in an Engineering Course.

It is obvious from what has been said that there is increasing recognition that engineers must also be educated and cultured men and that the present engineering school needs to alter its methods in order to bring about this desired result. The best available remedy evidently lies in the adoption of as much as possible of the usual college course in the arts or in science. In other words the results would be better if professional training were subordinated or possibly entirely eliminated in the undergraduate years. Harvard University presents the only example of the trial of such complete elimination. Through seven years before the merging of her graduate school of applied science with the Massachusetts Institute of Technology, Harvard exacted a baccalaureate degree for entrance to courses in engineering. It is possible that the proximity of these two great schools prevented a fair trial of the plan, or it may be that it was too long a step in advance. It is generally conceded, however, that his first attempt at a strictly graduate school of engineering did not prove itself the desired method of correction of the existing imperfections in engineering education.

Undoubtedly the conditions would be greatly improved and the status of the profession of engineering more clearly defined if the formal professional training of engineers were given only in graduate schools. In such circumstances, however, seven, if not eight years of college and university training would be necessary for the student. The necessary probationary period following graduation would doubtless add two or three more, bringing the total to ten years before the student entering college could hope to earn a fair living as an engineer.

Now to a greater extent than in any other profession the student of engineering looks to it as an early means to a livelihood. And this he may safely do, for the profession, also to a greater extent than any other, offers numerous subordinate positions, such as those of draftsman, operator, inspector, etc., all requiring, for a beginning, only a moderate amount of professional training. Further, a sufficient training for these positions may be safely given in a four-year undergraduate course. Indeed, by taking advantage of the flexibility of the elective or group system, this training may be given in a curriculum which differs but slightly from a standard course for a baccalaureate degree in arts and sciences. The common mistake up to the present has been in the attempt to give a more extensive if not complete professional training in the undergraduate years, with the unfortunate result already described. In many cases, courses of this nature give the student very little more than a high grade of polytechnic training. The student naturally does not realize the limitations of this type of training, and if he can look forward to a degree in engineering from a college in good standing at the end of four years, he is not apt to see the advantage of four years of general studies before taking up the purely professional courses. Every school of engineering in the country now offers professional training in undergraduate years, and many of them confer degrees suggesting professional qualifications on their completion.

The time scarcely appears ripe, therefore, for the strictly graduate school of engineering. The more promising method at present seems to lie in the modification of the existing four-year curriculum, so as to include as much as possible of the present courses in arts and science; in the offering at the end of four years of a degree which indicates preliminary training only, and in the offering of graduate courses and subsequent degrees, indicating the completion of formal professional training.

The Undergraduate Course at Johns Hopkins.

The undergraduate curriculum which has been adopted at Johns Hopkins University with the particular purpose of remedying some of the imperfections which have been mentioned, extends through a period of four years. It is believed that some form of reward should be offered to a student satisfactorily completing this period of work. This reward should not, however, indicate a completion of educational training in engineering, but should serve as a point from which those students who are not qualified either by taste or natural aptitude to continue in more advanced professional study, may nevertheless enter with credit into engineering work under the direction of others. The first three years of this four-year course will be followed by all students. The first two years will be devoted to mathematics, physics and English, and there will also be one year of work each in modern languages and in chemistry. In the third year there will be three courses, one each in the elements of civil, electrical and mechanical engineering. All three of these courses must be followed by all students. A course in political economy, in which it is intended to introduce the elements of business law, finance and organization, will also be pursued in this year. Mathematics will be continued through one half of this year, and a course in hydraulics will occupy the other half. The fourth year will offer two courses in each of three branches of engineering, specialized professional study being thus restricted to this year. To these will be added a course in logic, ethics, and psychology and one elective such as geology, chemistry, biology mathematics, or other subject. Drawing will be taught through all four years. It will begin with training in free-hand and work uniformly through courses in mechanical drawing up to the graphical treatment of the special problems of the fourth year. Laboratory work in the first two years will be limited to the subjects of physics and one other science. In the last two years the student will divide the time allotted to laboratory work between the drawing room and the engineering laboratory.

Special insistence is made on the training in physics, which extends through two and one half years. A general demonstrational course covering the whole field of physics continues throughout the first year. The class work is accompanied by the carefully organized laboratory course long existent at Johns Hopkins. The second year of work comprises the introduction to the mathematical theory of mechanics, and thermodynamics. In the third year the mathematical theory of electricity and magnetism serves as the introduction to the first course in electrical engineering. In mathematics the first year of work embraces analytical geometry and an introduction to the calculus,—the second being devoted almost entirely to the differential and integral calculus and to special problems in connection therewith. The half-year course in the third year is in differential equations.

PROVISION FOR PRACTICAL WORK.

Courses in manual training, shop work, foundry work, etc., often found in the curricula of engineering schools, have been omitted from the prescribed work of the college year. It is believed that such instruction as may be necessary in these branches should be obtained at other times. The available time in a course extending through only four years can be spent to much better advantage in class-room instruction or in laboratory work which bears more particularly on the applications of the particular branch of engineering. It is recognized however, that shop work and manual training, thus omitted from the regular instruction, are nevertheless desirable and it is intended to provide opportunity for them during the summer months. All students will be encouraged to seek contact with professional work during this period, and effort will be made to secure occupation for as many as possible. Should the plans which have been made in this direction develop satisfactorily, one of the requirements for graduation will be that a student shall have passed at least four months in a manufacturer's shop, in the employ of some public utility corporation, in the office of a consulting engineer or in some other occupation bringing him into direct contact with the application of engineering principles. During one of the summers a part of the training in civil engineering will consist of a course in surveying. This course must be followed by all students and it is intended to have it follow immediately after the close of the academic year.

SUMMARY OF THE UNDERGRADUATE COURSE.

Briefly summarized, this course differs but slightly from a course leading to the degree of bachelor of arts with mathematics and physics as principal subjects, and with courses in engineering substituted for the usual electives. The student will know something of each of the three principal branches of engineering, and will have had two successive years of study in these branches. While, under this plan, the special instruction in a particular branch of engineering is somewhat curtailed when compared with that of the other better-known engineering schools, the greater number of educational studies and the better fundamental training are obtained at the expense only of courses covering advanced theory and the analysis of special applications of the different branches of engineering. It is believed that with increased insistence on underlying scientific studies, and on the central principles of the different branches of engineering, familiarity with such special applications as the student may have missed in his four-year course will follow promptly without trouble when he encounters them at a later date, and a substantial foundation will have been laid for subsequent study of advanced theory. It is also believed that the graduate will be quite as well, and probably better, prepared for beginning engineering work under the direction of others, than graduates of those schools in which professional instruction begins early in the course, to the sacrifice of educational studies, and in which the effort is made to take a complete survey of the entire field of a particular branch of engineering during four-year course.

The general character of the new course may be understood from a comparison with those of five of the better-known schools of engineering in the East, on a basis of the proportion of the total time allotted to each subject. This comparison has been made in detail for all subjects. For the purposes of this discussion all the subjects may be divided into three groups: (1) general educational and cultural studies; (2) scientific studies underlying professional courses, being principally mathematics and physics, and (3) professional studies. In the new course in the Johns Hopkins University the studies of group (1) consumes 24 per cent. of the total time; the percentages in the five institutions studied vary from 2 to 16 per cent. For group (2) the percentages are; Johns Hopkins, 42 per cent., other institutions, from 30 to 40 per cent. For group (3), professional studies, Johns Hopkins, 30 per cent., the other institutions, from 45 to 58 per cent.

Graduate Work.

While the university has thus given most careful consideration to the problem of the creation of an undergraduate school, it has nevertheless had constantly before it the question of graduate activity in the field of engineering. As already stated, the conditions of the legislative bill are extremely liberal, leaving the university practically unhampeed as to the particular direction and character which should be given the work of the new school. The bill, in fact demands an "advanced" character for the school. It would be possible, under its liberal terms, to devote pactically the entire resources provided to the development of graduate work. In the light of the university's history and traditions this plan has in fact appealed strongly to a number of its members. However, from the survey made by the committee which studied this phase of the question, it did not appear evident, for reasons which have been already mentioned, that a strictly graduate school of engineering could be introduced at this time with a prospect of success unless accompanied by a carefully planned undergraduate school from which material might be drawn. Further, the discussions during the time the legislative bill was under consideration, the conditions surrounding the award of the scholarships provided, and several other features of the bill make it certain beyond all question, that its obvious intent was that an undergraduate school should be an integral part of whatever plan might be adopted.

While, therefore, it has appeared advisable to give first attention to the creation of an undergraduate curriculum, the development of an accompanying graduate school is considered one of the most important ultimate aims. and announcement has been made of the courses and facilities for graduate study. In the graduate school, opportunity will be offered the student to procure complete formal training in any single direction he may elect within the three branches: civil, electrical and mechanical engineering. The graduate courses will cover not only the special applications omitted from the undergraduate courses, but will also include discussion of the progress of engineering achievement. Important features of this work will be the continual review of current engineering literature and also the conduct of a seminary in each branch of engineering. In this way contact will be maintained with the present state of engineering practice and achievement, and the student will develop, and present evidence of his ability to make comprehensive review and study of special problems.

It is in connection with the graduate work that the university expects to identify the department of engineering with its history and traditions. Experimental investigation and research will be encouraged in every possible way. The organization of the work will be such as to enable the professors to devote a large part of their time to the guiding of the students in this work, and to the taking of active personal part therein. The new laboratories are being particularly designed to provide, in addition to the requirements for the undergraduate work, special rooms and equipment to meet the needs of experimental investigation. It is hoped that intimate relations may be developed with the State and municipal activities requiring the services of engineers, and also with manufacturing companies with the aim to study their special problems, and to open promising lines of experimental research.

DEGREES AND GENERAL ORGANIZATION.

At the end of the four-year undergraduate course a baccalaureate degree will be conferred which will indicate preliminary training in engineering. The graduate courses will lead to the degrees in civil engineering, mechanical engineering and electrical engineering, two years after graduation in the undergraduate course of this university or their equivalent. Should the student desire to proceed further with special study and investigation, the degree Doctor of Philosophy will be open to him, subject to the regulations of the university in connection with that degree.

The department of engineering is an integral part of the organization of the university. The general and fundamental studies of undergraduate years will be conducted in the same class-rooms and laboratories and by the same professors as those of the corresponding courses in the college of arts and sciences. The undergraduate work of the first two years will be under the direction of the Board of Collegiate Studies. The professional studies of the graduate and undergraduate period will be directed by the faculty of engineering, under the direction of the advisory committee of the department of engineering. This committee, consisting of the president of the university and eight professors, will make recommendations through the president to the trustees on all questions pertaining to the conduct of the department.

Beginning in October, 1914, all professional studies, laboratory work, and research will be conducted in the new laboratories at Homewood, the beautiful site in the northern section of Baltimore, to which the university is now in process of removal. The design of the laboratories has been most carefully studied, and they will be equipped with every facility for carrying out the purposes which have been briefly outlined in this paper. A detailed description of the laboratories has already appeared in several other publications.

DISCUSSION.

Professor Wm. T. Magruder: What is the relationship of the engineering college of the Johns Hopkins University to the State of Maryland?

Professor Whitehead: The story of the creation of the school is given in the first page or two of the paper. The relation with the State of Maryland is limited to the creation of a certain number of scholarships, and there is no control or supervision by the state save in the assignment of these scholarships. A condition of acceptance on the part of the university was that there should be no state control.

Dean F. L. Bishop: Does not the condition of acceptance prescribe that students must have passed an undergraduate course?

Professor Whitehead: Not explicitly. That is what I referred to as "local conditions" in the paper.

Professor W. L. Upson: The institution of an engineering course at the Johns Hopkins University is a great event, and Dr. Whitehead need not apologize for bringing it to the attention of the Society. There are, however, a few questions which have been suggested to me by the paper. Dr. Whitehead states that drawing will be taught during the four years. From the standpoint of the electrical engineering students this goes against what seems to be the modern trend. Again I note that an advanced course in physics serves as an introduction to the first course in engineering. I had an advanced course in physics myself, and remember some of its difficulties. I remember, for example, the subject of potential. When we had our first examination, an oral one, the professor asked me what potential was. I replied that I could give the definition but that I had no idea what it meant. He volunteered to explain it, and very kindly gave me an explanation which, also, I did not understand.

I have since then obtained a definite idea of potential, and can repeat the definition I learned in the class-room. I can now give a definition from the standpoint of a mathematician, but it is quite different from the standpoint of a junior. This and other topics of advanced physics are perfectly clear to one after he has been through the whole thing, but as an introduction to electrical engineering, I do not think that the student gets much out of them.

It is different in the senior year, as I know from the interest which our seniors at Union College take in non-electrical physics and in mathematics.

Professor Whitehead stated that the time does not seem ripe for [illegible] in engineering. I wish to ask if the time ever will be ripe for it. I rather think that we shall never get to the point where we ought to have a purely graduate course for electrical engineers. Experience at Union College shows that we can get all the graduate students we want for nine out of twenty-three senior students in electrical engineering expect to come back to us for graduate work next fall. In electrical engineering that is quite remarkable.

Professor C. F. Harding: It has been the custom to consider as the fundamentals of the engineering course physics, chemistry and mathematics: and many schools give as much weight to chemistry as to physics. Many engineers attach great importance to the chemistry, but I understand that it is minimized in the new course of study, as compared with physics and mathematics.

Professor W. M. Wilson: In all the discussions by practical men which have been referred to by Professor Whitehead, he states that the objections to the present work of the engineering schools were their attempts to specialize under three heads: First, that the graduate has no practical judgment of affairs, due to his lack of contact with affairs; second, that after graduation he takes the position that because he has had unusual opportunities for education, he is still entitled to further advantages over "the other fellow"; third, that his vision has been narrowed so that he cannot appreciate broad sociological principles which a successful engineer must appreciate thoroughly. Now of these criticisms the condition complained of in the third opposes the other two.

It seems that the Johns Hopkins University has taken the opposite path from that involving the coöperative principles. Of course, it has not been determined absolutely that the coöperative principle is right, as it has been in operation only eight years, but here is the proposition as we see it. We will assume that a man cannot get a complete education in any college: that a college is not a brain factory. All we can do is to create a desire for knowledge that will keep a man progressing in practical work. Now if a student is taken through a college course which contains no specialized studies and which brings him into contact with teachers of high class, when he comes out of college he enters into an entirely new set of conditions than those which previously surrounded him where he studied. Some young men may cease to maintain an interest in study when they are put up against the serious conditions of labor and manufacturing companies. If you bring a man through the productive course of engineering, then he is subjected to no change when he graduates except a change for the better; and, because he is relieved from that intellectual pressure, he can work under better conditions.

Dean A. H. Fuller: I believe that the most of us are requiring too much advanced technical work and that we are doing this at the expense of a thorough understanding of fundamentals and of general training.

I was interested to learn a year or two ago that in Northwestern University less time is given to advanced technical subjects in their five-year course than in the usual four-year ones. The new course at Johns Hopkins seems to have been planned along the same line.

I am not sure that it would be best for us all to follow the same plan, for the conditions under which different schools do their work are not the same. But there is no doubt in my mind that the student who takes a course like that outlined has an advantage over one who does not, even if he spends no more than four years in college provided, however, that he believes in the fundamental principles underlying this plan of training. When we force such subjects as English and political science upon students in the freshman year their value seems doubtful; later in the course they realize the necessity for that kind of work and will elect it if given an opportunity.

In the last year of the course at Johns Hopkins a certain amount of philosophy or logic is mentioned. It was not clear to me from Professor Whitehead's paper whether that work was definitely prescribed. I believe in a certain amount of philosophical work in the course for the man who wants it, but think it should be left to the individual to decide which of the different desirable subjects shall be taken.

Professor W. H. Timbie: It seems to be agreed that the necessary thing in education is to stick to the fundamentals, but there is disagreement as to the best way to teach fundamentals. The experience of the Westinghouse school of salesmanship should prove instructive to teachers. At first the beginners were put in school for two or three months to learn salesmanship, being sent out to the district offices later. That plan was not successful. Now they are sent out at the start and stay out as long as they can without becoming discouraged. When they have found out what they have yet to learn, they are sent into the school and given the necessary training. The month or two in school are then well spent. The students' zest for fundamentals was acquired out on the job. I think that the nearer the school gets to actual conditions on the outside, and gives a sense of these to the student while he is in school, the better will the student appreciate the meaning and importance of the fundamentals and the better will he be prepared to face these outside conditions later.

Professor C. R. Young: Dean Fuller has expressed something of my thought in regard to the spending of too much time on technical subjects. Our experience at the University of Toronto has shown that there is little advantage in giving a great deal of attention to higher studies; that the weeks put in on suspension bridges or cantilevers, for example, are to a large extent wasted on the majority of students. But few of them will ever be engaged on works of a monumental nature. We think it is better, therefore. to have ordinary structures discussed before them, such as simple bridges, buildings, towers, tanks, standpipes, chimneys and structures of that kind. The average student has difficulty in applying ordinary, simple principles to even these structures. We are trying to give him help in searching for and applying the proper principles to these problems, without going into much detail I do not believe in preparation of detail shop drawings in universities. If a man is provided with the tool, and has tested its edge in preparing a few detail drawings, he can successfully attack the actual drawing problems very soon after he goes into the bridge company's office.

Professor C. F. Scott: In our discussion we have dealt with matters in the schools and not enough with what we expect our students to do after they leave the school. This has been mentioned, to be sure, but in many discussions the remarks have covered the methods to be employed rather than the purposes which we want to accomplish. Underlying the discussion there has seemed to be the idea that we are training men who would become research men in physics and electricity, or designers, who would need their higher mathematical training for the solution of the problems of research or theoretical investigation. The majority of students do not follow these pursuits. Their fields may be quite different, and the question may well be raised whether the training these men get is that which best develops and fits them for the work they are to perform.

Professor G. S. Morrison: The great man was the warrior in the olden time; later he was a lawyer; and in the future he will be the engineer. The public is looking now to the engineer to solve the problems of the present and the future. The president of a syndicate which is operating a score or more of public utilities said recently: "We want men for all departments; men who can go into our financial department, and give us the fair statement of a property; who can estimate its possibilities of extension and tell how much money should be spent in developing it, and who can advise us as to the best method of financing the property. We want men who can operate these companies, who can become superintendents and managers. We want engineers over the whole range of that field which is very largely the engineering and the science of public utilities properties." Now we find that the men of this syndicate would rather take high school boys than graduates of the universities, as the former has less to unlearn.

In the employment of college graduates the best results in all departments are secured from men trained in engineering courses, and in general, in electrical engineering course. These men are better than those trained in economics courses because the engineering training teaches them to respect the truth, to draw real conclusions from real data. Engineers deal with the present where the lawyers deal with tradition. The men trained in real things are the best men for the general activities of today.

There has been underlying most of our thought the idea of producing engineers who can use mathematics, design things and do research work. Of these actually comparatively few are needed but in the work of the world engineering problems must be dealt with also. It has been stated that two thirds of the graduates of engineering schools are engaged in executive rather than purely engineering work.

Dr. Whitehead has given us something of a constructive nature. He is taking an old college course and making it into a course for engineers. He is putting many matters of an engineering nature into the courses in physics and mechanics. This may be right if these departments will do the work as it should be done for engineering students. I had three courses of mathematics, one of which was abstract and useless to me as a prospective engineer. Another was very valuable to me. The great thing is to coördinate all of the courses to yield the training which we want our students to get.

Professor E. W. Kellogg: As I understand it, the curriculum at Johns Hopkins, insofar as it departs from the custom elsewhere, is an effort to meet the criticism that engineering schools are overspecializing at the expenses of thorough training in fundamental principles. There is no doubt that many courses are put into engineering curricula which do not increase the student's usefulness to the manufacturer or other employer to any great extent. For example, I think that unless an extraordinary amount of time is put upon it, a course in scientific management would not take the place to any extent of the courses the manufacturer would want to put his new recruits through. This fact constitutes a strong argument for leaving out courses of this kind, or at least for cutting them down considerably.

It is quite agreed that the courses in mathematics and physics are of the utmost importance, and if the student fails to get them in college he will probably never get them. That is the difference between the applied courses and the fundamental courses. If one does not get the fundamentals in college he will never get them while the material covered in the applied course in college can be acquired later. The problem, in many cases, is to determine whether or not the applied engineering courses should be cut down for an increased amount of time to be spent on fundamentals, and it seems to me that the right answer to that question depends much on the manner in which the two kinds of courses would be taught. If more time is allowed for mathematics, will it mean increased time put on a comparatively limited field and, therefore, greater thoroughness, or will the professor take advantage of the increased time to go into ramifications of his subject that may be interesting to a mathematician, but cannot be considered as direct preparation for the student's future work? If the teacher tries to cover a wider field in mathematics than the student will need in his future work, it may be questioned whether it is of any more value for one to spend his time on that mathematical drill than to spend it on some specialized engineering course.

For the specialized course I want to say two or three things. In the first place it holds the interest of the student to a greater degree than the earlier courses. I remember the increased zest I felt as a student when I began studying the practical applications of the general principles I had been wading through, and began putting my mathematics and physics to some real use.

Again the fundamental courses do not touch on the economic side of engineering problems. The advanced courses are needed to give the student a truer appreciation of the nature of his future work. The applied engineering courses in the field of electricity would relate to railways, power plants and telephone work. These take up many economic studies, giving the student an idea of the systematic analysis of costs. They give him an engineer's viewpoint, making him realize that practical engineering is two thirds economics and one third technology.

In the next place, have we considered the value of the applied engineering courses as reviews of the fundamentals? Nearly every one of them takes up new problems whose solution calls for the use of the fundamental principles previously studied. The working of new problems involving familiar principles, constitutes the best kind of a review, quite as effective in fact as a formal one. Again, the advanced courses bring one into contact with the human phases of engineering, which have great educational value, and into contact with questions that are social, psychological, economic and sometimes governmental.

For these reasons I believe it would be unwise to say that the advanced courses should be sacrificed for the sake of more time for the fundamentals, until we are certain that the needed extra drill in fundamentals cannot be embodied in the advanced courses.

Professor Whitehead: With reference to the question as to drawing through all four years, this statement of the requirement should be qualified in the case of students in electrical engineering. Somewhat less will be required of them, but we hope to insist that every student shall have a sound knowledge of the principles and methods of drawing as a means for showing design.

I do not think that the theory of physics taught after the student enters the professional courses will have the same value as when taught before those courses. The exact reasoning and relationships which must be understood in the underlying theory of physics are, to my mind, very essential to the appreciation of relative values in the engineering studies.

Replying to the question as to degrees, we shall give the degree of bachelor of science in engineering to all students completing four years of work, and without regard to the particular branch of engineering in which they have specialized. We shall also offer the degrees of master in civil engineering, master in electrical engineering and master in mechanical engineering at the end of two years more. The degrees of doctor of engineerng and doctor of philosophy will be available at the end of two years more, on completion of the usual requirements in the Johns Hopkins University for those degrees.

A course in surveying is required of all students and occupies the first five weeks of the summer between the second and third years.

With reference to the suggestion that we must leave out some of the strictly engineering courses in order to make room for the fundamental studies which we emphasize, I would say that this is correct. Nevertheless, in each one of the subjects of engineering we have two years of consecutive work, and in the fourth year practically the entire time of the student will be devoted to his particular subject. Our reasons for believing that the graduate in these courses will be as well equipped as a graduate of those courses in which the engineering studies begin in the first and second years are given in the paper.

Chemistry is given through one entire year and in a course consisting of four hours of class work and six hours of laboratory work. There is also an elective study in the fourth year, for which chemistry may be offered.

Replying to the question as to the standing of graduates of other institutions, we shall certainly not ask any such graduate to take up any of the fundamental work of our undergraduate course should he come to us for advanced work. He has standing with us as a graduate student, with the usual rights pertaining to that class of student, but if it is found to be necessary that he follow any undergraduate engineering courses, he must conform to the undergraduate regulations pertaining thereto.

It has been suggested that we should not claim to turn out a finished engineer at the end of four years. I state in the paper that we make no such claim. We regard our graduate as only a beginner, but a beginner who will be better prepared for undertaking engineering work under the direction of others, than graduates of those engineering schools which give less fundamental training in their effort to cover the entire field of any branch of engineering in four years. Our course is particularly designed on the basis that an engineer should be an educated and cultured man. We also believe that the two years of succession of training in the principles of any single branch of engineering will enable our graduates in the long run to go further than those who are without this fundamental and cultural training.

The course in philosophy in the fourth year is required of all students. It continues through the entire year and contains the elements of logic, ethics and psychology. We have included this as a part of our plan to give the students as good general cultural training as may be possible, in addition to training in the fundamental sciences and subsequent courses in engineering.

Briefly summing up again the general purpose of this new course, I will say that we have considered carefully, and for some time, the criticisms of a number of engineers, manufacturers and educators of the shortcoming of the average engineering graduate of today. These criticisms point out the lack of general education, the poor powers of expression both in writing and speaking, and the absence of understanding of fundamental scientific principles underlying the engineering studies on the part of graduates. In order to meet these criticisms we have planned the course which is described in my paper. Replying to the suggestion that the contemplated elimination of certain courses in the usual engineering curriculum but not in our own, we point out that we have only eliminated those portions of the usual engineering curriculum which bear on special applications as distinguished from general principles and methods. We offer as exhaustive a treatment of every particular engineering application as may be desired in our graduate courses.

While we may be wrong in the plans which we have adopted for correcting existing imperfections, we do not think so ourselves, and we venture to hope that the results of our work will indicate that we have taken a step in advance in engineering education.

PROPOSED COURSES IN STRUCTURAL ENGINEERING FOR CIVIL ENGINEERING STUDENTS.

BY W. M. WILSON,

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INTRODUCTION.

The civil engineering department of the University of Illinois is about to put into effect a revised course of study. Before doing this it has seemed advisable to make a careful study of the field of structural engineering to ascertain what portions of the work should be presented to the student and the best method of instruction to be used. The course as outlined has not been adopted by the department, but represents the writer's idea of what such a course should be if it could be made to coordinate properly with the other work of the engineering college. The work is intended for students who wish to specialize in structural engineering. Students in civil engineering not wishing to specialize in structural engineering should be given an option of other groups of related subjects.

A course in structural engineering should include instruction in the selection of the type of structure; the principles involved in the design of a structure from the footings to the completed superstructure; the application of these principles to actual design; and sufficient practice in making working drawings to familiarize the student with details of construction.

The instruction should be given in such a manner as to provide mental training; develop initiative and give sufficient practice in the execution of details to make the student of some economic value in engineering work immediately upon graduation. In making up the course which follows, the writer has endeavored to apply these principles in such a way as to best utilize the time available.

The course as worked out is given in the following summary. The number of semester hours devoted to this part of the work agrees with the number provided by the department in the proposed new course of study.

SUMMARY.

Junior Year, Second Semester.

Stress Analysis.—The determination of stresses in bridges and buildings by graphics and analytics. Two three-hour drawing-room and three one-hour recitation-room periods per week. Credit, 5 semester-hours.

Structural Details.—Use of hand-book, reading blue-prints, writing shop bills and making details of connections and main members of steel bridges and buildings. One three-hour drawing-room and one one-hour recitation-room period per week. Credit. 2 semester-hours..

Senior Year, First Semester.

Bridge Design.—Designing, detailing and writing shop bills for steel railway bridges. Three three-hour drawing-room periods per week. Credit, 4 semester-hours.

Masonry.—A study of the various materials used in masonry construction, types of structures, testing materials and designing. Two three-hour laboratory and three one-hour recitation-room periods per week. Credit, 5 semester-hours.

Stresses in Reinforced Concrete.—A theoretical study of the stresses in reinforced concrete structures. Two one-hour periods per week. Credit, 2 semester-hours.

Advanced Stresses.—A theoretical study of deflection and of the stresses in complex steel structures such as continuous girders, arches, movable bridges, suspension bridges, portals, and structures having redundant members. Three one-hour recitation-room periods per week. Credit, 3 semester-hours.

Second Semester.

Building Design.—Designing and detailing steel mill and office buildings. Three three-hour drawing-room periods per week Credit, 3 semester-hours.

Reinforced Concrete Design.—The design of reinforced concrete retaining walls, bridges and buildings. Two three-hour drawing-room periods per week. Credit, 3 semester-hours.

History of Structural Engineering.—A historical sketch of the various types of structures which have been used. One one-hour lecture per week. Credit, 1 semester-hour.

DESCRIPTION OF COURSES AND SUGGESTIONS.

The work in stress analysis should consist of the determination of stresses in simple steel structures by graphic and algebraic methods. These methods have been combined in one course because it seemed more desirable to emphasize the determination of stresses than to give an extended course in either analytics or graphics. Where the two methods are given separately there is a temptation to give different applications of a method rather than to give the best solution of a particular problem. A larger amount of work applicable to the practical design of structures can be presented in a limited amount of time by presenting the two methods simultaneously than by presenting them as separate courses.

Lessons should be assigned in the text and the recitation period utilized to help the student to understand the subject matter presented. At the same time, problems should be assigned for the student to solve during the drawing-room period under the supervision of an instructor. By having the problems solved in the drawing-room it is possible for the instructor to make oral suggestions while the work is being done which is much better than criticizing work already done.

Each student should be required to determine the stresses due to dead load, live load and wind load in the following structures: roof truss, steel bent of a building, through girder, deck girder, and Warren, Pratt and bowstring trusses.

The work in structural details should consist of instruction in the method of making up sections of members and in the method of designing details to connect the different members which make up a structure.

The student should be assigned problems to familiarize him with the various shapes of structural steel manufactured and with the tables of information found in the steel hand-books. He should then be given shop drawings of various members of different structures and required to write shop bills. This would give him practice in reading drawings, and make him familiar with the methods of billing material and of making up various members. He should then be given data governing the design of various members and required to determine the sections. After becoming familiar with the make-up of sections of main members, he should be given a shop drawing of various connections and required to compute their strength after which he should be given the sections of members and required to design the connection.

The details of both buildings and bridges should be included in this course..

The work in bridge design should consist of the design of railroad bridges. Each student should be required to make a set of design calculations, a design drawing, a shop drawing and a set of shop bills for one plate girder span; a set of calculations, a stress sheet and a shop-detail drawing of the stringers and floor-beams of a through-truss riveted railroad bridge and to check a set of similar calculations and drawings. Students desiring to do more than the minimum amount of work required should be given an opportunity to make a design drawing of the trusses.

In most of the studies which the student has had up to the end of the junior year, instruction has been given in detail. This has given him a knowledge of the sciences and has given him discipline in the execution of work. He has not had practice in choosing proper values for factors upon which design depends. He may be able to design a deck-plate girder span 60 ft. long with girders 7 ft. deep and 6½ ft. apart but may not know why a deck plate girder was used or why the dimensions were fixed at the values given. This course is intended to give some practice in exercising judgment in the determination of those factors. In order to do this, in assigning problems in bridge design instead of fixing all the factors upon which the design is based, the student should be given a field survey of the bridge site and required to design a crossing. This makes it necessary for him to choose the type of bridge and fix all dimensions.

The course in masonry should be devoted to the study of masonry construction. Sufficient recitations, quizzes, problems, designs and laboratory tests should be required to make it necessary for the student to learn the most important principles and to learn where to find and how to apply the large amount of information available. During the first half of the semester both laboratory periods should be devoted to testing materials. The student should be required to test samples of cement to see if they conform to specifications; to test samples of mixed sand and gravel to determine the amount of either one or the other to be added to give the resulting mixture the proper proportions of the two materials; to test the various masonry materials to determine their physical properties, and to make a test of the bearing power of soil.

This work makes the student familiar with the method of conducting tests such as are made of the materials used in large and important structures. It also gives him a first-hand knowledge of the materials and of the specifications which could be obtained in no other way.

During the second half of the semester the two laboratory periods should be devoted to the design of masonry structures. Each student should design a bridge pier, a bridge abutment and the foundation for a building, each design to include a working drawing and a scheme for construction.

The courses in stresses in reinforced concrete should be devoted to the theory of such stresses and, in addition to developing the theory, the student should be required to make the calculations for the design of such elements of construction as girders, slabs, columns, etc.

In advanced stresses attention should be devoted to the determination of stresses in the more complex structures. The course should include general study of such subjects as continuous girders, suspension bridges, movable bridges, arches, portal bracing, structures having redundant members, deflection and secondary stresses. In addition to giving the student a general knowledge of this broad field, he should be required to make a thorough study of the stresses in one or more of these more complex structures.

The course is made up largely of advanced mathematics and is apt to be unpopular. It should therefore be administered in such a way as to stimulate interest, not only so that the students may do good work in class but, if possible, so that a desire for further investigation may be created.

The course in building design should be devoted to the design of steel buildings. The theory for determining the stresses and the method of making details have been covered in earlier courses. It remains to apply the knowledge gained in these courses to the design of buildings. Each student should be required to design at least a steel skeleton mill building and a steel skeleton office building.

In designing the mill building each student should be given the overall floor dimensions of the building and the purpose for which it is to be used. He should be required to outline the general scheme of the building such as the number of bays, type of columns, trusses, etc. After the general scheme has been approved by the instructor the student should be required to make a stress sheet and typical details.

In designing the office building the student should be given a plan showing the column spacing and an elevation showing the number of stories and the clear height of each. He should be required to decide upon the type, and make the design for the floor, roof and spandrel walls. Each man should be required to make floor plans, wind calculations, column loads, and column schedules. The more ambitious should have an opportunity to do additional work by carrying out the design in detail.

In the course in concrete structures each student should be required to design a through or deck-girder bridge span, a retaining wall and a building. The design of each structure should consist of a complete set of calculations and design drawings. Students able to do more than the minimum amount of work should detail the reinforcing bars, estimate the quantities of material and design the forms.

The historical sketch of the development of structural engineering should cover the various steps in the development of the present types of structures and the advantages of the succeeding types. Considerable time should be devoted to describing the more important types of structures being built at the present time and to pointing out the conditions to which each is most adaptable.

A great deal of the work, as outlined above, is to be taught in the drawing-room. The success of any course depends largely upon the method by which it is administered. Drawing-room courses have been in general use for only a short time as compared with recitation-room courses and the best method of administration has not been so carefully worked out. Considering the opportunities which the drawing-room offers for efficient personal instruction, courses in drafting are too unpopular. The subjects taught are recognized by the students as being important and should be interesting to one preparing to enter the engineering profession. This being true, it would seem that any unpopularity which attaches itself to such a course is largely the fault of the method by which it is administered.

The writer wishes to make the following suggestions relative to the administration of drawing-room courses.

1. Insist upon thorough training in the prerequisite subjects so that it will be unnecessary to make any extended re-

view of ground already covered. If too much time is given to such a review, the better students who already have the work well in hand will conclude that the course is to be only a "rehash" of what they have already done, and will lose interest. The leaders must not be discouraged as they are the ones who are depended upon to put life into the class and pull the others along with their enthusiasm.

2. Make all assignments clearly so that the student knows exactly what he is to do. This does not necessitate, however, giving so much information that there is nothing left but a problem in mathematics. The assignment may be clear and concise and yet a number of factors may be left to the judgment of the student. What is desired is that he understands clearly the end toward which he is working. If arbitrary restrictions on the solution are desirable they should be clearly stated, but it should be understood that if no such restrictions are specified the student is subject only to the general rules governing good design.

3. Instruct the student how to do the work. Men in engineering offices, doing the same thing over and over, have gradually evolved what they consider to be the best method. The instructor should acquaint himself with this method, convey the information to the students and insist upon their applying it to their work. By insisting that the student work in accordance with a carefully prepared plan he learns the most efficient way of working, covers more ground during the course, has the discipline of following instructions and the work is in a shape much more satisfactory to both student and instructor. The loss of experience in working out a scheme of attack for himself is more than offset by the benefit derived from following out a well-planned scheme.

To help the student follow the prescribed method, sample calculations and sample drawings should be available for him to refer to.

4. The instructor should keep in touch with the student's work as it progresses to see that he is working along the right line. It is not enough to look over a finished drawing and

mark the mistakes, as a basis of giving a grade. It should be examined while it is being made and the difficulties analyzed, the teacher pointing out the detail that is wrong, showing why it is wrong and explaining how it should be corrected.

5. Numerical accuracy should be insisted upon. Having the calculations made in a neat and orderly manner promotes accuracy. Having the students check each other's work is good training for them and relieves the instructor of a large amount of drudgery.

If the instructor conducts his class in the manner outlined above, his course will be valuable and interesting. However, such close supervision on his part will be exhausting labor and it will be necessary to reduce the number of hours of drawing-room instruction required of him to a reasonable value.

These courses as described conform to the requirements as set forth at the outset. Some phases of the work which it would be desirable to include have been omitted because of lack of time. Chief among these are practice in making estimates of cost, more practice in the determination of stresses in complex structures, especially arches, and practice in making shop drawings.

Some experience in estimating the cost of structural work might well be included in a course in cost analysis which should be included in a civil engineering course. The amount of time required to determine the stresses in a complex structure is so great that it is impossible to do much along this line. As was pointed out before, all that can be accomplished is to take up the several structures in general and perhaps one in detail and to try to create interest on the part of the student for further investigation. For practice in making shop drawings the student must wait until he gets into commercial work.

THE NEW GRADUATE COURSE IN MECHANICAL ENGINEERING AT COLUMBIA UNIVERSITY.

BY CHARLES EDWARD LUCKE,

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Since the establishment of the so-called standard American four-year course of study for the professional degree of mechanical engineer, about a half century of time has passed. In that time the profession has advanced far more, in intensity and complexity of problems successfully solved, in methods of attack developed and adopted, and in participation in general industrial affairs, than for the whole period of its previous history.

The four-year course of study is still the standard professional preparation in spite of the fact, nowhere disputed, that the sort of preparation needed today is vastly different from what was satisfactory when the present older schools were established. More or less general efforts have been and are being made to adjust the work of the professional school to the requirements of practice along lines as numerous as the men or schools engaged in the work, so that while the four-year period is still the standard, the disposition of that time is most varied, far more so than mere catalog announcements would lead the casual reader to believe.

The latest and probably the most radical of these attempts to raise the standard of preparation to somewhere near the requirements of present day professional practice is that of Columbia University. According to this new plan all students, beginning with 1915, are required to pursue a prescribed course of engineering study for three years after fulfilling, under the academic department or college, the requirements of a series of preparatory or introductory subjects. These subjects normally require three years for completion and are equivalent in credit to the B.S. degree. This new plan is identical in general scope with Columbia's solution of the similar problem in the professional schools of law and medicine. Just what reasons have led to the adoption of this system for the training of engineers is not at the present times a matter of so much general interest to engineers, engineering instructors, and other schools, as is a statement of just what is to be done with the time available; the *why* and *wherefore* of the plan may be found in the statement of what it is, here presented for the first time.

Subjects required for entrance and to be studied in the more or less standard science college course, fall under three classes: first, those that are primarily cultural; second, those that constitute essential preparation for the study of mechanical engineering; and third, those that serve to bridge the gap from a purely preparatory to the real engineering point of view and are properly introductory engineering courses. The time devoted to each is indicated by points, one point being one hour per week per term, or 14 hours total for lectures or recitations, twice this for drafting room and three times for shop or laboratory.

ENTRANCE SUBJECTS FOR THE GRADUATE COURSE IN MECHANICAL ENGINEERING.

Group I. Cultural.

Subject.	Points.
A. English	9
B. Philosophy	6
C. French or German	6
D. History	6
E. Economics	3
F. Political Science	3

Group II. Preparatory.

Subject.		Points
G. Mathematics	Algebra	3
	Analytical Geometry	3
	Calculus	12

H. Physics	Mechanics and Wave Motion	6
	Heat and Light	6
	Electricity	6
	Laboratory	3
I. Chemistry	General Inorganic	10
	Qualitative Analysis	10

Group III. Introductory.

Subject.		Points.
J. Drafting	Mechanical Drawing	4
	Descriptive Geometry	3
K. Analytical Mechanics		2
L. Mineralogy		3
M. Theory of Surveying		2

Subjects of Columbia Graduate Course in Mechanical Engineering.

First Year.

Department.	Subject.	Total Hrs.
PHYSICS:	1. Physical Laboratory	42
	2. Analytical Mechanics	84
CHEMICAL ENGNG.:	3. Industrial Chemistry	42
	4. Engineering Chemistry Laboratory.	84
METALLURGICAL ENGNG.:	5. Metallurgy of Iron and Steel	28
	6. Metallurgical Laboratory	42
CIVIL ENGNG.:	7. Hydraulics	28
ELECTRICAL ENGNG.:	8. Electrical Machinery	28
	9. Elements of Electrical Engineering.	28
MECHANICAL ENGNG.:	10. Power Machinery	56
	11. Machine Elements	140
	12. Shop Processes	126
	13. Mechanical Instrument Laboratory.	42
	14. Hydraulic Laboratory	42
		812

Of the total of 812 hrs. 52 per cent. are in laboratory, drafting or computation rooms.

Summer:	15. Shop Practice	320

Second Year.

Department.	Subject.	Total Hrs.
Civil Engng.:	16. Resistance of Materials	84
Electrical Engng.:	17. D. C. Machinery	28
	18. A. C. Engineering	28
	19. D. C. Laboratory	56
Mechanical Engng.:	20. Engineering Thermodynamics	168
	21. Mechanics of Machinery	140
	22. Machine Analysis	140
	23. Machine Tools	28
	24. Pumps and Hydraulic Machinery.	28
	25. Compressors and Fans	28
	26. Compressor and Fan Laboratory ..	42
	27. Heat Transfer Laboratory	42
		812

Of the total of 812 hours 52 per cent. are in laboratory, drafting or computation rooms.

Summer	28. Design of Machinery	160
	29. Commercial, Shop, Factory or Power Plant, Inspection and Report	160

Third Year.

Department.	Subject.	Total. Hrs.
Electrical Engng.:	30. A. C. Machinery	28
	31. A. C. Electrical Laboratory	56
Law:	32. Business Law	28
Mechanical Engng.:	33. Steam Turbines	70
	34. Reciprocating Steam Engines	70
	35. Furnaces and Heat Transfer Equip.	28
	36. Water Power	84
	37. Steam Power	126
	38. Steam Power Laboratory	42
	39. Gas Power	42
	40. Gas Power Laboratory	42
	41. Factory Construction and Equipment	140
	42. Manufacturing Processes and Management	56
		812

Of the total of 812 hours 52 per cent. are in laboratory, drafting or computation rooms.

COURSES GIVEN IN THE DEPARTMENT OF MECHANICAL ENGINEERING.

The following is a syllabus of topics covered in the courses administered by the department of mechanical engineering, the course numbers and names corresponding with those in the above summary.

10. *Power Machinery:* Total time = 56 hrs.

Three systems of power generation, water, steam and gas, with main characteristics of each. Statistics of the use of power and each system in manufacturing, transportation and mining industries. Social and economic importance of use of power generating and driven machinery with review of the industrial revolution, general present day trend. Power generation as transformation of natural forms of energy into work and division into process and mechanism or machinery. Qualitative analysis of fundamental processes of each system, main and secondary, with development of typical forms of apparatus suitable for purpose, relation of function to form of all main elements of equipment. Steam power: boilers, boiler auxiliaries and fittings: fuel combustion, coal, oil and gas furnaces, mechanical stokers, chimneys, and draft apparatus, feed water heaters and economizers, superheaters, steam piping: typical reciprocating engines, valves and valve gears, regulation and governors, forms of main engine parts, lubrication, steam turbines, condensers and pumps; cooling towers and spray ponds. Coal and ash handling systems. Gas power; typical forms of explosive and non-explosive mixtures, gas and air mixing, proportioning, distributing and governing valves, and valve gears, typical forms of main parts, auxiliary apparatus for ignition, cooling, muffling, starting: adaptation to liquid fuel, vaporizers, carburetors, spray-nozzles, gasolene, alcohol, kerosene and heavy oil engines, coal, gasification, hard and soft coal gas producers, scrubbers and purifiers for lamp black, tar and dust, producer blast systems and humidification control. Water power: non-turbine water wheels and development of turbine principles, impulse and reaction turbines, wheels, settings and power houses, water supply, available head, pondage, dams, penstocks, flumes and controls. Auxiliaries to water power with reference to fluctuation of water flow.

The method of treatment is purely qualitative though analytical and such as to constitute a general introduction to later subjects in which the same topics are covered in sufficiently proper detail in a quantitative way.

11. *Machine Elements:* Total time = 140 hours, 56 class and 84 inspection and report.

An introduction to the whole subject of design and selection of machinery for specified duty, being an analysis almost entirely qualitative of the functions, forms, materials and limits of proportion adapted to varying service conditions. Stress is laid on the adoption of standards and attention given to the details of all adopted standards with analysis of reasons for adoption, also to failures and breakages and the modifications indicated as necessary. Commercial forms of type parts or details of construction, sizes, styles and trade names; functions of the elements and variation with service, nature of loading to which the element is subjected and relation to support, materials and relation to both service and fabrication requirements, proportions of standardized elements and rational methods of finding proportions of elements that yield to analyses and adopted empiric methods for others, selection from available standards of elements for any specified service. Sheet metal structures, riveted joints and autogeneous welds; bolt and screw fastenings, set screws, nuts, locks, wrenches, screws for power transmission, all types of screw and bolt threads; keys and fastenings, square Woodruff, feathers, gibs; cotterred joints for pump rods, crossheads, connecting rods, frame connections; force and shrink fits for cranks, car wheels, flywheel runs, guns, tires; pin and knuckle joints for rods, links, chains for transmission of power and for conveying materials, bayonet and screw sockets, loose connections, turbine blade fastenings; pipe joints for air, water, ammonia, gas, steam, acids, high and low pressure pipe, valves of all sorts, pipe hangers and expansion joints; couplings, flanged, split, rigid and flexible. Hook's, Sellers' Oldhouse. Clutches, jaw, Western plate, cone, multiple disc, Johnson magnetic; brakes, block band, cone, post electric; ratchets, stationary, running or silent, releasing escapement; axles, shaft and cranks, hot and cold rolled shafting; steam and water turbine shafts, car axles, machine spindles, mill shafts, crank shafts forged and built up; cranks for engines, pumps, compressors and driven machines; journal bearings for vehicles, electric generator and motors, turbines, engines, pumps, compressors, machine tools, light and heavy, high and low speed, mill-shaft hangers, wall and post boxes and pedestals; thrust bearings for propellor shafts, water wheels and steam turbines, and driven machines, such as dryers, mixers, separators, pulp grinders; sliding bearings for machine platens; crossheads; roller and ball bearings, knife edge, agate, flexing band; chain pin; pulleys, flywheels, drums, sheaves and sprockets, solid and built up for low and high speed and adaptation to chain, belt, rope and cable drive; friction gears, grooved, cylindrical, conical, for constant and variable speed ratios; toothed gears, spur, bevel, herringbone, spiral, worm; belting, leather, canvas, rubber, steel, and fasteners; rope and cable, hemp, manila, cotton, steel and bronze, wire; chains and hooks, open and stud hooks; Ewart, roller, Renold and Morse chains, special links for conveyors. Valves, stop, reducing, control, regulating, relief, safety, vent, hand, float, pressure and speed operated for all fluids; springs, elliptic, spiral.

flat, helical; stuffing boxes and packing for valve stems and large rods, all fluids and services; cylinders for steam, gas and oil engines, compressors, pumps, hydraulic presses; flat plate members, hand and manholes; cylinder, valve chest, condenser and tank covers; long column members, piston and connection rods; pistons and plungers for driving and driven machines, all fluids; frames for heavy and light vibration, non-vibrating, static machines and vehicles; lubricating systems and devices for oils and greases, all types of surfaces. In the time devoted to inspection and report reference is made to actual machines and selected standard elements themselves, to journal, trade catalog and manufacturers' blue-print illustrations.

12. *Shop Processes:* Total time = 126 hours, 42 in class and 84 inspection, computation and report.

Methods of attacking problems of construction and quantity production in the shop. Two methods of production, making, and manufacturing, explained and analyzed, fundamental distinction in use of end measures and gauges for manufacturing and line or graduates scales in making. Making parts fit gauges instead of each other. Origin of machine tool working and present place in production. Accurate measures; line and end and influence on organization of shop, one reducing labor and other overhead costs; relation of accuracy and cost, accuracy and interchangeability. Precision and commercial workmanship in shop economy, three kinds of accuracy: form, size, position; form and position important to both systems, size only to manufacturing system. Accuracy of form, illustrated by scraped surface plates, a fundamental process, use of surface plates and straight edges and influence in maintaining accuracy of planers typical of function of process of work, other applications of scraping to originating of correct squares and angle plates, importance of correct squares, methods of originating angles, and index plates, use of surveying instruments in the shop. Measures of length fundamental to sizes, the inch, yard, original and method of copy; vernier multiplying lever and microscope; end gauges, snap, plug and ring, reference disks. Swedish gauges. Measuring machines, importance of uniform contact pressure, Watts, Whitworth, Sweet, Pratt & Whitney, Brown & Sharpe and Newall methods, precision screw fundamental to measuring machines, precision lathe for cutting screws, Rogers and National Physical Laboratory of Great Britain; Micrometer calipervernier and multiplying lever. Gages, limits of application, limit gages, adjustable and fixed, screw thread and Star gage. Fits and limits, definition of allowance tolerance and limit, shaft and hole bases of fit, press and running fits, taper fits. Turning and boring, methods of dealing with large work, pit lathes for large diameter, gun lathe for long work, turrent lathe, from mill plane and turrent chucks reamers reaming, pilot bar, forming tools; automatic and magazine turret lathes, multiple spindle machines, substitutes for turret, Lo-swing and Fay lathes. Special tools and fixtures illustrated by turret lathe, importance in the manufacturing system, balance between cost of specials and increase of production. Floor plate work. Analysis of production data of lathes and boring mills. Drilling, types of machinery and production data, multiple spindle, removable heads, jigs, drills with vernier and micrometers for spacing, button disk indicator and master plate methods of spacing. Milling operations on different types of machines, Brown & Sharpe universal, vertical spindle, large slabbing machines, rotary planers, profiling, cam cutting, thread milling, milling cutters and cutter grinders. Gear cutting; forming cutter system, automatic machines; generating system; Bilgram machine; octoid tooth system, Gleason machine; Fellow's system and machine; hobbing process and machines, Newton and Mesta machines; analysis of gear cutting data. Grinding, comparable in importance to scraping, Brown & Sharpe, Norton, Pratt & Whitney, Heald Machine Work. Balancing rotating parts and machines for the work. Laying out work. Assembling large floor and small bench work, one man and squad system. Forging, comparative value of light and heavy hammers, competitive value of forging press. Flanging and shaping, single stroke and step methods, dies, bulldozers. Pattern and foundary methods and relation of production costs to methods.

13. *Mechanical Instrument Laboratory:* Total time = 42 hours in the laboratory.

An introduction to and preparation for the important work of experimental mechanical engineering, involving an analysis of the principles of operation of standard measuring instruments, their calibration error and limits of utility. Instrument-makers' catalogs and text-books are relied upon for data, but personal experience with at least one example of each type is required. A short explanatory lecture or quiz precedes each laboratory period. Pressure measurements, simple and multiplying manometers with light and heavy liquids, narrow and wide tubes, meniscus observation, standard and special forms for gas condensing vapor and liquid low pressures; pressure and vacuum gauges of Bourdon and diaphragm forms, recording low gas, draft and high pressure gauges, steam engine indicator for intermittent pressures; temperature measurements, thermometers and pyrometers, solid, liquid and gas expansion types, vapor pressure, fusion points, calorimetric radiation and electrical methods and types, indicating and recording forms; direct and indirect methods of measuring weights, volumes, areas, lengths of solids, liquids, gases, vapors; time and velocity measurements, instruments controlled by pendulums; periodic vibration of springs and tuning forks and the laws of falling bodies, chronographs, instruments for measuring angular velocity; methods and instruments for determining the effect of variation of speed, bearing pressure and temperature upon the coefficient of friction of a lubricated bearing; methods and instruments for determining combustion efficiency, use of the Orsat apparatus and various types for measuring gas flow, orifices, Pitot tubes, Venturi meters and representative types of commercial meters; instruments for determining the suspended moisture content of steam; instruments for determining the relative and absolute humidity of the atmosphere; measurement of work and power, absorption and transmission dynamometers, indicated work and power of piston engines, pumps and compressors.

14. *Hydraulic Laboratory:* Total time = 42 hours in laboratory.

An experimental demonstration of the basic hydraulic phenomena for perfectly frictionless, non-viscous, non-compressible fluids and the peculiarities introduced by real liquids due to non-homogenous and friction flow, volatile or of large viscosity. Hydraulic phenomena; proof of Bernoulli's theorem by measurements on water in a converging-diverging tube set at an angle to the horizontal; proof of Toricelli's theorem by the law of the parabola, modifications by the use of viscous oil and volatile gasolene, capillarity by flow in small tubes, center of pressure determined by force to open a flap valve, hydraulic grade line by measuring head at different points of a pipe line of varying sections on different levels; parallel flow and convergence of water path in sudden contraction of cross section by lamina of colored liquid in glass tubes; critical velocity in pipes by threads of color in water in glass tubes; transmission of pressure by comparative measurements of a pump driving a hydraulic press in operation; weir flow for trapezoidal, rectangular and triangular for all rates of flow, use of hook gauge, effect of surface curve on head reading, cross currents and suppression of contraction, aeration of nappe. Pitot tube constants for variable velocities, orifice, sizes and form, mode of attachment and pipe stream lines, pipe traverse for mean velocity head by differential manometers; Venturi tubes and nozzle, discharge constant for all velocities of air, free and aerated water, function of cones in tubes and nozzles, peculiarities of spray nozzles; pipe flow constants for loss of head, per 100 ft. of length of straight pipe, effect of surface conditions, diameter and velocity; cross section changes, head lost for typical structures, pipe connections, pump passages and valves; impulse and reaction turbines, horsepower and efficiency for fixed head, all speeds and gate openings, reduction to equivalent performance at one foot head and estimation of performance at other heads, study of ratio of peripheral to jet velocity; pumps, triplex driven and direct acting steam, slippage and analysis of all head lost, with corresponding efficiency for all heads, valve lifts and spring tensions, speeds, suction pipe temperature and lift; centrifugal and turbine pump; efficiency for all heads and speeds, analysis of performance to one foot head and prediction of performance for other heads.

15. *Shop Practice:* Total time = 320 hours in first summer.

General methods. Tools and materials. Classification of materials and methods of forming and joining; wood, iron, steels, bronzes and brasses; soft metals. Shaping by cutting; flat and curved surfaces; boring, punching, slotting, planing, milling, screw cutting. Shaping by pressure; rolling mill for iron and steel, steam hammer, drop hammer, bolt and nail making, die pressing, drop forging, stamping, riveting. Special preparatory or finishing treatments for materials, seasoning timbers, tempering, annealing, case hardening, malleablizing of iron and steel.

Pattern making and foundry. Draft, shrinkage and finish allowance, patterns with and without cores, solid patterns, core prints, core boxes, split and loose piece patterns, master patterns. Types of patterns, pulleys, cylinders, machine tool parts, pipes, presses, skeleton pattern follow boards, gears, worms, worm wheels, valves, hoppers, propellers. Sweep and loam work, sweeps and posts, shute boards, iron planes, flat, middle and regular sweeps. Wood working tools and typical operations for each, universal saw bench, band saw, joiner or hand planer. surface planer, wood trimmer, speed lathe, pattern makers' lathe, vertical boring machine. Tool grinders. Hand cutting and measuring tools. Metal melting and pouring. Rough finishing of castings.

Forging, plate work and pipe fitting. Materials suitable for forging wrought iron, steel, mild and crucible; steel forging, heating, hammer refining; red hot and cold short overheating, burning; welding, lap, butt, scarf and cleft welds, autogenous electric and thermit welds, gas flame cutting, hardening, decalescent and recalescent points, magnetic tests, heating in lead, hardening with clay, quenching and hardening baths, case hardening, tempering, colors; annealing air, pack and water annealing. Furnaces for heating, annealing, tempering and welding with oil, coal and gas fuel. Forging machines, steam hammer, deep hammer, power hammer, hydraulic presses, power presses, steam, belt and air drives. Shaping machines, bull dozers, eye benders, chain machines, riveting. Tool making of high speed, B special high speed, Jessop XXX, Bethlehem XX and X, Midvale, Novo, Syrian, Argus, Recut, Mushet, self-hardening steels. Use of tools, hand hammers, fullers, swages, flatters, set hammers, chisels, punches, calipers, squares, swage blocks, surface plates, special tools and vise. Pipe and fitting, cast iron, black or galvanized wrought iron or steel, copper and lead.

Machining, fitting, and erection. Typical equipment of machine shops and machine tools. Cutting tools, materials, shapes, cutting speeds and tool-feeds, pulley and belt speeds. Milling machines, plain, vertical and universal: typical operations, face and slot milling: boring key seating, fluting, gear cutting, hob and worm wheels, bevel gears, helical grooving. Grinders, abrasives, wheel shapes and grains, dry grinder, universal flat disc grinder, iron disc emery cloth glued, wet tool grinders, drill dividers, universal grinders for accurate cylindrical, conical and cam surface. Planing machines, shaper, slotter, and planer. Lathes, tool makers, gap lathe, axle, wheel, turret, pulley, crankshaft, precision and speed lathes. Drilling machines for drilling counter boring, reaming, tapping, spotting, facing: sensitive drill, upright drill, radial and universal drill. Fits and fitting, fitting processes, forcing fits by presses, shrinkage, driving and running fits. Limit gages and allowances, and reference gages, standard cylindrical gages and calipers. Measuring tools, rules, scales, try square, micrometer caliper and square, vernier caliper, straight-edge, bevel protractors, tapers and angles. Bench and vise work, locating working points on flats, cylinders and drill centers; hammering and sawing, stretching, threading and tapping, chipping hand and air tools, grooving: filing, cross diagonal draw filing: scraping planers, V waves, surface plates: keys and key fitting: breeching and drifting and breching machines. Belting selection, lacing, clamping and tension adjustment. Pulleys and alignment. Erection methods and equipment.

20. *Engineering Thermodynamics:* Total time = 168 hours, 112 in class, 84 problems.

Quantitative analysis of the performance of all sorts of thermal apparatus and derivation of equations for numerical computation from fundamental laws and thermo-physical, thermo-chemical constants. Work, units and determination in terms of pressures and volumes, graphical representation to P. V. coördinates, mean pressures, work of expansion, compression and cycles and relation of cycles to indicator cards, velocity and horsepower of jets in free expansion, horsepower, mechanical efficiency of piston apparatus. Work and capacity of compressors, mean pressure and horsepower per unit of capacity, low and high pressure delivery, hot and cold, for logarithmic and experimental laws, single, two and three stage with intercooling, with and without clearance for all gases, dry and moist air, natural and manufactured gases, and vapors and all ranges of pressures. Compressor diagram factors, variable capacity compressor systems, maximum work of compressors.

Work and computation of piston engines using any fluid, compressed gases, air, wet or superheated steam, in single or multiple expansion cylinders, with and without clearance, with and without compression, any cutoff or ratio of expansion; any size of receiver for multiple expansion with or without reheat, and any phase relation between cylinder events. Mean effective pressure, water rates, water-rate-load; Willans line forms, mechanical efficiencies and diagram factors for all cases. Thermo-physical and chemical constants and their use in engineering calculations. Temperature scales, quantities of heat and work equivalent, coefficients of expansion and pressure rise of solids, liquids and gases, relation of density to molecular weight, specific heats, vapor pressure-temperature relations for vapors, boiling and freezing points for pure liquids, mixtures and solutions. Latent heats of fusion and vaporization and relation to vapor density; gas-vapor mixtures, humidity, dew-points, relative weights and volumes. Combustion and related reactions, combining weights, volumes and composition of products, heats of reaction, of formation of products, and of formation of compounds. Absorption of gases by liquids and solids, heats of absorption and dilution, total and partial. Heat exchange and transmission, convection, radiation, internal conduction, boundary resistances, mean overall coefficient with velocity for liquids, submergence for evaporating liquids and mass flow for gases. Fuel composition; air requirements and products. Manufactured fuels and their properties, roasting and distillation processes and products; coal, coke oven gases and coke, crude, distillate and residue oils and oil gas; reaction processes with air and steam blasts, blast furnace, water and producer gases, yields, efficiencies, calorific powers. Combustion effects, temperature pressure and volume changes for explosive and non-explosive combustion, heat suppression factors, dissociation and variability of specific heat limits, temperatures of ignition and limits of proportion for explosive combustion, rates of combustion and explosive propagation. Steam boiler heating surface capacity, absorption and overall efficiency, linear law of boiler heating surface capacity and logarithmic law of efficiency.

General laws of transformation of heat into work and special forms of equations for relations between physical constants, and for work done in terms of heat for single phases and cycles. Temperature entropy coördinates for graphic representation of heats and work of cycles. Typical cycles, cyclic and real thermal efficiency for vapors and gases. Cyclic analysis. Performance of real engines compared to cyclic, efficiency and mean effective pressure factors. Application of general work-heat equations to flow of expansive fluids, critical pressure ratio, special forms for high, medium and low pressure ratios, nozzles, orifices, valves, pitot, venturi, pipe and duct flow; convection flow in flues and chimneys. Compressed air engines and compressor combinations; single and multi-stage with and without preheat and reheat, real and apparent efficiencies. Mechanical refrigeration, fluid per hour, displacement horsepower and water per hour per ton refrigeration, for ammonia and carbon dioxide compression, ammonia absorption, and dense air systems.

The treatment throughout is quantitative and on every topic thorough drill is given in the solution of numerical problems of strictly engineering character involving the exercise of judgment as well as the selection and derivation of suitable equations and constants.

21. *Mechanics of Machinery:* Total time = 140 hours, 56 in class and 84 in drafting or computation room.

Study of typical pieces of mechanism to secure any given motion of a working part of a machine, with determination of the force acting on each member of the machine by reason of the work done or its mass-motion characteristics. A necessary preliminary to the design of machinery for specific duties and coördinate with the proportioning of machine members once their external loading and motions are known. Motions of machine members to obtain prescribed motions, typical prescribed motions; general method of motion analysis in trains of mechanism; motion of a single member; connecting rods about instantaneous axes of rotation. Connection of parallel shafts by spur, bi-lobular gears and friction wheels, cams, belts, chains, ropes, links, couplings and slider crank chains. Connecting intersecting shafts by bevel gears, toothed and friction, cams, belts, couplings; non-intersecting shafts by worm and wheel, skew gears, hyperboloidal gears, belts, ropes. Changing rectilinear to rotary motion by rack and pinion, slide crank chains, screw and nut, cams, Scotch yoke. Analysis of typical trains of mechanism such as shapers, drills, spinning frames, printing presses. Mechanism for straight line and parallel motion; ratchets and other special forms. Velocity and acceleration of machine members analyzed by algebraic and graphic methods for evaluation of dynamic forces or velocity characteristics such as rate of opening or closing valves; linear velocity and acceleration of sliding members such as pistons; angular velocities and acceleration of rotating members such as turbine rotors, flywheels, gears and gear trains. Static force relations in machines analyzed by graphic and algebraic methods to determine member loads and support reactions, stress diagrams for complete members for loads and reactions; similar analysis of dynamic force relations and total member loads, due to both static and dynamic forces; torques and power to drive, rotating parts, flywheels, discs, drums, governors, gyroscopes and high speed shafts. Reciprocating parts, piston machines, tool rams and platens, hammers. Cyclic mass-energy characteristics of machines, impacts and centers of percussion in hammers and riveters. Friction, analysis of causes, limits, data for sliding, rolling, journal and step bearings, belts, ropes, brakes and clutches. Flywheels for controlling angular displacement with given accelerating fires, turning efforts, resisting forces, mean efforts and resistances, resonance. Balancing and vibration in machines, forces and couples, rotating and reciprocating parts, standing and running balance. Governors and speed regulation, functional characteristics from types for various limits and services, pure centrifugal, pure inertia, combined centrifugal and inertia, power and sensitiveness of governors, resistances and reactions of mechanism controlled by governor, time of action, limiting and damping, mean speed governors.

22. *Machine Analysis:* Total time = 140 hours, 56 in class and 84 in drafting or computation room.

Determination of suitable dimensions of machine parts of given general form to resist given loads, with due reference to shop construction limitations, life, stiffness, strength and costs of production. Both analytical and synthetic methods are used but special attention is given—first, to analysis of existing adopted forms especially those known to be satisfactory and those that have failed with reasons, before any attempt to predict or design new parts for given specifications. Classification of materials and properties suitable for machine parts, physical and chemical and heat treatment; material specifications. Rational selection of working stresses for strength, stiffness and life. Proportions of riveted joints for pressure tanks and boilers, braces, stays and supports, modifications for tanks, bins and ship hulls. Dimensions of bolt and screw fastenings for fixed, smooth and vibratory parts, and of screws for transmission of forces, long and short screws in tension and compression; keys and cotter joints for fixed, sliding and adjustable connections; pin, knuckle and universal joints; shrink and force fits; screwed and flanged pipe joints, pipes, and flues, expansion joints and brackets. Loading, straining action, speed, capacity and dimensions of couplings and clutches, plate, ring cone, insulating, flexible. Proportions and capacity of brakes, block band post disc coils, electric and hydraulic. Dimensions and service limits of ratchets and escapements. Mill and machine shafting strength, rigidity, speeds, keyway and journal effects, crank shafts suffering bending and twisting. Special high speed turbine, fan, separator, shaft dimensional problems, torsional vibrations in long shafts and synchronism, maximum stresses. Proportions of spindles for low and high speed, all loading conditions, car, locomotive, tractor and automobile axles. Cylindrical journal bearing proportions for heating and wear, all conditions of load, speed, material, lubrication and support, both intermittent and continuous service; thrust and step bearings for vertical and horizontal loads; sliding bearings, vertical and horizontal guides; limiting pressures, speeds and stiffness of supports. Roller and ball bearings, journal and thrust types, load distribution to parts and limiting proportions for speeds, loads and form, effect of accuracy of workmanship, materials. Analysis of unusual bearings and bearing failures to determine causes. Proportions of flywheels and pulleys, solid, split and built up, cast iron, steel plate, wood, hubs, spokes, rims and fastenings, dimensions and forms of drums and discs, turbine discs and drums, hoisting drums, relation of strength to speed, form, loading due to attached parts. Dimensions, proportions, speeds and capacities of friction driven gears, worm, toothed wheels of all sorts. Horsepower, life and dimensional relations of belts, ropes, cables, and chain-drives of all sorts, including connecting wheels, limits of application of each form. Dimensions of hooks, clevises, shackles and turnbuckles, influence of curvature on straining action. Proportions and sizes of valves of all kinds with reference to adjustment pressures, volumes passed, velocity of flow, life. Spring dimensions for given loads and materials, flat leaf, spiral and helical. Dimensions of friction draft gear and shock absorbers. Proportions of stuffing boxes, glands and packing, steam engine, air compressor, gas engine, pump and press cylinders and connections with and without liners, thick and thin. Flat plate members, forms and proportions, plain, ribbed, disked and built-up, dished and coned modifications. Dimensions of long column members, connecting, piston, push and eccentric rods, frames, columns including shanks, caps and bolts, for all sorts of service loading. Proportions of pistons, plungers and rams, disc, cone and built-up, special treatment of slender and broad plungers, wall and bottom thickness and sizes of bolts, rings, springs and packings. Frame dimensions including housings and bed plates, curved, straight, tubular box and ribbed, relation of form and position of support to strength and straining, stiffness limits.

23. *Machine Tools:* Total time = 28 hours.

Construction and operating characteristics of standard types of machine tools, detailed comparison of form, costs, sizes, types and adaptability to different classes of work. Engine, tool makers, gap, gun, axle wheel, pulley, crank shaft, precision, speed, turrent lathes; lathe drives, belt and motor; life, depreciation, variations in accuracy, efficiency, valuation of used lathes, present and replacement values. Milling tools plain, universal, circular, cam, vertical, spindle, profiling and screw thread milling tools. Machines for broaching, broaches, pitch of broach teeth, general angles, keyway cutting. Drills, machines for thread cutting, Acme, American Screw, A. S. Cook Co.; dies and cutters. Machines for boring and boring bar cutters, horizontal and vertical. Grinding machines, dry and wet, cylindrical conical profiles, abrasives and wheels, size of grain, strength of bond, character and speed. Planing tool shapes, cutting speeds, feeds for all classes of cuts. General procedure in selection tools for complete shop equipment. Methods of management and maintenance of machine tools. Machine tool specifications.

24. *Pumps and Hydraulic Machinery:* Total time = 28 hours.

Type construction of pumps for different classes of service and such details with dimensions as affect capacity, efficiency or life. Review of principle of conversion of pressure and velocity head, hypothetical and actual suction lifts for various temperatures and substances pumped, ratio of suction lift to vapor pressure. General arrangement of pump ends, single, duplex, triplex, single and double acting; piston and plunger, submerged piston, straight way types. Outside center and end packed plunger pumps, materials, pressures, forms, efficiencies, volumetric and hydraulic, mechanical, indicated, pump capacities and speed limits, pump power. Pump valves, construction and losses; disc valves, seat area, lift, spring, loads and materials; conical valves vs. flat seat, clapper and ball valves, metal, leather, rubber and fiber faced valve. Development of direct acting pumps, spring, steam and exhaust thrown valves, relief valve motion; defects of single pumps and suitability for large quantities of air with water; the duplex pump, valve motion, lost motion, cushion; multiple expansion direct acting pumps; horsepower, cylinder ratios, duty based on steam and coal heat, indicated and test, test duty with analysis of losses. Selection of pump type and size for service; boiler feed; condenser auxiliary, wet vacuum, hot well, circulating; elevator pumps and regulators; waterworks, mine pumps; high pressure hydraulic press and pipe line pumps; accumulators. Vertical pumps; single acting, deep well and differential plunger pumps; duplex single acting, wet vacuum pumps; Edwards' suction valveless air pump; triplex single acting with expansion engine and power drive, duplex double acting, all services. Power pumps, large water works crank and flywheel pumping engines and high duty direct acting pumps. Centrifugal pumps, fundamental equations and special forms, curved radial, and back curved vanes with corresponding dimensions, capacities, efficiency, and characteristics, shutoff pressure, breakoff point and vane angle effects, volute and turbine pumps. Pump condenser characteristics. Jet pumps, pumps for mechanical lubricators, positive rotary pumps, pulsometer pump, hydraulic, Humphrey gas pump. . Hydraulic presses, accumulations and control valves.

25. *Air Machinery:* Total time = 28 hours.

Typical construction, principal dimensions and performance of fans, blowers, compressors of given capacity, pipe lines and appliances for using compressed air and other gases. Review of thermodynamics of compression and development of short cut methods of commercial computation for single, two and three stage machines, application to commercial sizes, cylinder capacity, machine speeds and horsepower, friction and horsepower to drive. Types of compressors, dry and wet, water piston, Taylor hydraulic compressors, reciprocating and rotary, single, duplex and triplex for low pressure non-jacketed, and high pressure single and multistage jacketed, details of construction that affect efficiency, cost and life, including intercoolers. Crank efforts of compressors and necessary flywheels, main bearings, pins and rods with allowable pressures and stresses. Intercooler and aftercooler construction, cooling surface, effect of humidity, reheat and reheaters. Compressor valves, mechanical, semi-mechanical and automatic, structures and compressor performance with different types of valves, efficiencies of compression and volumetric, slippage. Regulation of compressor capacity, variable and constant speed compressor governors and regulators, with part vs. full capacity efficiencies. Layout of air compression plant, loads, load factors, costs and selection of type of compressor and drive. Pumping by compressed air, the air lift, displacement pumps and return air systems. Air and gas pipe transmission, quantities, losses and dimensions. Fans and low pressure blowers, types and sizes for different surface, equations for capacity, pressure, speed, and power. Turbo-compressors for low and high pressure for conveyors and blast furnaces, theory of turbo-compression, commercial construction of guide vanes and impellers, constant volume governors and regulation. Compressed air tools, rock drills, slipping and riveting hammers, rotary air drills, tempering machines and compressed air engines, forms and efficiencies.

26. *Compressor and Fan Laboratory:* Total time = 42 hours in the laboratory.

Experimental demonstration of the laws of compression and expansion of gases, and gas movement in pipes and ducts, with investigation of the losses introduced by typical apparatus. Single and multi-stage air compression, jacket heat, valve loss, volumetric efficiencies, diagram factors, work per unit of air compressed, delivery temperatures, intercooler effect for all speeds, initial and final pressures, the ratio to include the critical for maximum work; fan capacity, efficiency, speed, equivalent orifice and delivery pressure relations for large and small speeds; pipe flow head losses, in terms of diameter, velocities, and density for gas and air, equivalent resistances of bends and changes of cross section; comparative accuracy of different methods of measuring gases, large and small quantities, orifices, venturi tubes, pitot tubes, wet and dry displacement and proportional meters, turbine and calorimetric meters, influence of density, temperature, humidity; compressed air engine efficiency with and without preheat, limiting exhaust temperatures, admission, cooling with cylinder temperature range, and speed.

27. *Heat Transfer Apparatus Laboratory:* Total time = 42 hours in the laboratory.

Experimental determination of the laws governing the transfer of heat in typical commercial apparatus and special apparatus designed to illustrate particular phenomena; effect upon the rate of heat transfer of characteristics of the transmitting and receiving fluids, superheated or saturated steam, gases and liquids; effect of material and form of dividing wall between the fluids; effect of variation in liquid velocity and of gas mass flow. Apparatus used for investigation of the above, surface condensers and multiple effect evaporators, steam boilers, ice machine refrigerating and condensing coils, liquid heaters, air heaters and steam superheaters. Heat transfer by evaporative liquid cooling as illustrated by cooling tower, spray or vacuum dryer. Gas furnaces.

28. *Design of Machinery:* Total time = 160 hours minimum, no maximum, drafting room.

With a proper ground work on the analysis of the movement of each element of a machine, its displacement, velocity, acceleration, and member load, in the course in mechanics of machines, the suitable and acceptable forms for such machine elements, in the course on machine elements, tho analyses of internal stresses in a member under any external loading and the resistances of materials, in the course on resistance of materials, and the application of the last relations to determination of proper dimensions of a loaded member, in the course on design of machine elements; the work of this course can be, and is, directed at once to the coördination of all these by drill in actual design of machinery. From a list of quite different but typical machines a group is selected yearly and students are assigned to the complete design of one of each or a line of sizes of one, ending with a set of detailed shop drawings and bill of material for shop orders; determination of tools needed for production in a given shop supposedly required to build the same and the kinds of jigs, fixtures and gauges required for manufacture of a specified quantity, assembly and inspection. Estimates are also required on costs by the methods of total weights, areas of finished surface and time study production data.

The following types of machines are used: Cranes, electric overhead, travelling, gantry, jib, walking; pumps, plunger, direct acting steam and triplex driven; machine tools, shaper boring mill, lathe; hydraulic, die and filter presses; engines, stationary, locomotives and marine, steam reciprocating, gas, gasolene and oil; mine hoists, steam, air and electric; steam boilers, pressure tanks and vacuum casings; steam turbine, centrifugal and turbine pumps; steam and electric driven air compressor; steam shovels, buckets and ladder dredges; small locomotives and automobiles; weighing and packing machines; wood-working machines, circular and band saws, planers, molders, mortisers, sandpapering; printing presses; rolling mills; wire-drawing and extruding machines; rock crushers and pulverizers; screens and separators for solid and liquid materials; pulp and paper machines.

29. *Commercial Shop, Factory or Power Plant Inspection and Report:* Total time = 160 hours minimum, no maximum limit, in second summer.

Practical contact with daily operation problems of a plant in service, to deveplop a clear understanding of ordinary troubles of operation, maintenance and repair, supply of materials, reports of performance, methods of meeting output changes and maintenance of low costs, control supplies and efficient use of labor. Special study of construction of units and their connection, the essential dimensions and capacities of all parts, analysis of operation of whole plant into elements with contribution of each unit. Reports are required in specified form, giving data, the obtaining of which insures the desired contact of student with plant equipment, and with men.

33. *Steam Turbines:* Total time = 70 hours, 28 in class and 42 in drafting and computation room.

Service conditions peculiarly adapted to turbines and analysis of statistical data on first cost, maintenance, space, foundations and steam consumption. Review of fundamental principles of the Rankine steam cycle and modifications for determination of jet velocities and flow weights with and without nozzle reheat, by temperature entropy methods for all conditions of initial pressure, quality, back pressure and reheat factors. Essential relations between jet velocities, vane, linear and wheel rotative speeds; the problem of low speed and high economy. Single stage impulse turbines, sizes and typical constructions, analysis of steam consumption data, determination of Rankine cycle factor for all imposed conditions, division of whole heat loss into elements, means for controlling individual losses, data on extent of successes attained, in reducing losses in nozzles and vane friction, wheel windage, bucket spilling, gland leakage, bearing friction; governor action; determination of proper number and dimensions of nozzles, wheels and bucket clearances. Compartment compounded impulse turbines, typical constructions and performances analyzed as for single stage with addition of leakage between compartments, friction on guide vanes; effect of number of stages on economy and costs and determination of principal dimensions. Multi-pressure-velocity compounded impulse turbines, effect of number and distribution of pressure stages on previous analyses;

Curtis-Rateau type of impulse turbines, analysis of performance and prediction of dimensions and performance for given specifications. Single and double flow reaction turbines treated as in other classes with additional reference to end thrust and stage leakage. Disc and drum turbines, marine turbines, low pressure turbines; bleeder turbines, tangential flow turbines; proper types and sizes of turbines for driving fans, turbine pumps, electrical and generators, combined analyses of performance of both driving units. Mechanical construction problems of the steam turbine, bearings, wheels, shafts and critical speeds, expansion, balancing, end thrust, dummy pistons, clearance control, wheel chamber drainage, blade forms and fastenings; governors, and governor valves, throttling, intermittent admission, number of nózzles, overload bye-passes, emergency stops, lubrication. General method of selection of turbines and specifications for purchase and sale.

34. *Reciprocating Steam Engines:* Total time = 70 hours, 28 in class and 42 in drafting and computation room.

Analysis of the performance of all classes of reciprocating engines and individual engines from the thermodynamic, cost and service standpoints; comparison of indicator cards and card factors of these engines and their Willan's lines. Comparison of valve motions of various classes of engines with a view to determining their limitations by means of valve diagrams. Determining the best initial steam pressure, degree of superheat, cutoff, ratio of expansion, clearances, exhaust pressure, and speed, best adapted to particular conditions from considerations of economy, life and service. Comparison of classes of engines as to distribution of turning forces for constant load and given load changes and as to location and intensity of serious stresses; also as to distribution of frictional resistances and relation of friction losses to useful work done. Detailed study of types of each class of engines; plain slide valve, high speed and low speed, automatic four valve and Corliss engines of both simple and multi-expansion types, including poppet valve and uniflow engines. This study to include purposes for which adapted, cost, efficiency, operation, maintenance, and final economy, including fixed charges and operating costs; also the effect on all these factors of changes in initial pressure, superheat, exhaust pressure, speed and size of engine. Comparison of individual engines of each class as to form, bulk, size and weight of various parts as related to the purpose to be served by each part. Purchase and sale of engines; specifications, contracts and guarantee both from the manufacturer's and from the purchaser's standpoint.

Installation, operation and maintenance of engines. Determination in case of several engines on same load of cutting in points for economy.

35. *Furnaces and Heat Transfer Equipment:* Time=28 hours.

Typical heating and cooling appliances analyzed as to relation between structural form and performance, based on fundamental laws of heat generation, absorption and transmission. Industrial importance of heating and refrigerating processes and apparatus, classification of apparatus as to purpose, and re-classification on bases of type process. Review of properties of fuels, gaseous, liquid, solid, natural and manufactured and characteristics of manufacturing processes, all with reference to efficient combustion in forms suitable for subsequent heat absorption. Temperatures of combustion, limiting superficial and volumetric rates in furnaces, efficiency of combustion, relation of radiant to hot gas heat. Gas-fired furnaces, gas burners, bunsen, blast and surface combustion for low and high temperature work: oil-fired furnaces, spray nozzles, air mixers, baffles and flame chambers, oil supply systems and feed control: coal and other solid fuel furnaces for high and low temperature operations, hand and stoker fired construction and performance with different fuels. Heat flow within a solid, internal conduction and resistance, temperature gradient, classification of substances into conductors and insulators, rate of internal temperature rise, cooling curves, skin temperatures and boundary resistances. Heat exchange between a solid and a liquid, laws and characteristics illustrated by metal quenchers, tempering and hardening baths, ice making in water, film resistances and means of reduction. Heat exchange between a solid and a gas, illustrated by checker brick, water gas carburetors, hot blast stoves, ingot soaking pits, ingot, plate, bolt, bar and rivet heaters, case hardening, malleablizing, tempering and annealing furnaces, brick and pottery kilns, enameling and core ovens, dryers, desiccators, melting or freezing, steam vacuum dryers for glue, soap, starch. Heat exchange between two liquids, illustrated by brine coolers, aqua ammonia exchangers, factory waste water heaters, liquid section of feed water heaters and condensers, parallel and counter current flow constructions. Heat exchange between a liquid and a gas illustrated by economizers, gas engine and gas furnace liquid heaters, automobile radiators, cold storage room piping, compressed air intercoolers, cooling towers, glass tanks, crucible and hearth metal melters; linear law of gas mass flow, controlling resistance of water velocity and gas accumulation. Heat exchange between two gases, steam superheaters, storage room dense air piping, compressed air preheaters, furnace wall and flue heat losses; a gas and a body changing state, steam boilers, stills, steam pipes, room heating radiators, direct expansion cold storage room and Gayley dry blast piping; two bodies changing state, multiple effect evaporators, steam jacketed kettles and vacuum evaporating pans. Typical and special structural forms of all apparatus are examined and studied with reference to life, efficiency of performance, and dimensions for given capacity.

36. *Water Power:* Total time = 84 hours, 42 in class and 42 in drafting and computation room problems.

Extent of present use of water power from statistics with analyses of influence of electrical transmission, development cost and cost of fuel burning, steam, gas and oil systems. Water power cost statistics and analyses into fixed and operating charge elements, importance of fixed charges and first cost of development of site. Water power rights. Typical water power sites, preliminary field work, gauging stations, topographical survey of drainage area and examination of runoff conditions for determination of available water supply; available head and runoff. Available power, the hydrograph and power curve, pondage and storage. Typical water power stations analyzed from two existing examples of each type of site and wheels. Comparison of different methods of development of same site. The turbine, impulse and reaction, fundamental conditions of operation of each, typical forms and analyses of efficiencies, influence of method of manufacture on form, and of form on efficiency. Turbine selection for site conditions, Holyoke tests and tests in place, derivation of formulas between speed, diameter and head, discharge and head, diameter and discharge, power and head, power and diameter, speed and efficiency; unit speed formulas and application to selection, reduction of Holyoke data to one foot head, plotting the standard test curves; selection of a turbine from test curves for different heads, loads and diameters. Turbine specifications for sale and purchase. Turbine governors, mechanical and hydraulic, and connection to gates, limiting speeds, problem of the open and the closed flume, hunting and racing, rate of gate movement, regulation test data and computations for regulation, governor specifications. Impulse turbines, analysis of test losses into components, effect of nozzle form on nozzle and overall efficiency and of bucket form and speed on bucket and overall efficiency, empiric formulas for bucket dimensions, effect of number of nozzles, runner diameter, and bucket angle, predicting efficiency. Reaction turbine analysis of overall losses into elements, effect of residual water velocity, speed, guide and runner angles on losses, gate opening mechanisms, involutes, determination of runner diameter, spiral casing layout. Turbine accessories, intake works, ice booms, submerged arches, trash racks, head gates, penstocks, flumes, relief valves for water hammer, surge tanks, gates, bearings, foundations, draft tubes, stop log and tail water gates, tail race.

37. *Steam Power:* 126 hours. 42 in class and 84 in drafting and computation.

Extent to which steam is used for power in manufacturing, mines and quarries and central stations, rail locomotion and steamships, with special analysis of statistics for manufacturing and central stations. Cost of steam power from statistics and analysis into fixed and operating classes and evaluation of elements in each. Controlling influence of load factor, fixed charges, fuel and labor, and variation of each of the latter with the first. Relation of thermal efficiency to fuel elements of power cost, and of type of standard equipment to first cost. Analysis of elements of plant into essential and refinements and power cost method of judging value of refinements. Analysis of load curves of existing plants, daily and yearly for all classes of service and prediction of load curves of new plants from summation of power demands of driven units. Selection of main unit sizes and type of equipment, estimation of probable thermal efficiency, space occupied, general arrangement, first cost and operating cost, preliminary to plant design. Steam engine and turbine selection from performance curves and cutting-in points for load curve, estimation of daily total steam. Boiler and superheater selection and estimation of daily coal from performance data, division of boilers into units and cutting-in points. Condensers and pumps; selection of type, size and probable useful value on basis of cost of ownership vs. saving in power cost. Similar analysis for feed water heating system, heaters and economizers, boiler feed, chimneys and draft equipment, fuel oil tanks and feeds, coal and ash handling, feed water purification, condenser water cooling. Other necessary or desirable auxiliary equipment, mechanical stokers, house service pumps, exciters, air compressors, lubricating oil systems; regulating devices, pump governors, damper and feed water regulators, indicating and recording gauges, thermometers, flue gas analyzers, relative value of using or omitting from cost and safety considerations. Piping, lagging, fittings, valves, types, systems, general layout and detailing for estimation of cost for steam, high and low pressure, main and auxiliary, boiler feed, general water, blowoff, drip, drip return, compressed air and oil and flumes for condensing water, elevators and conveyors, bins, tanks, repair equipment, cranes, power-house ventilation, heating, plumbing.

Revised estimate of total steam and water consumption, labor and repairs, first cost and total power cost by summation of all individual elements separately estimated. Systems of plant performance, records and reports and power cost accounting.

The drafting room work consists largely of computation and is carried along two parallel lines, analysis of probable costs, and performance for an existing plant, data for which is available, and layout of new plant for specified service, selecting units, making pipe layout and detailing with estimates of probable power costs.

38. *Steam Laboratory:* Total time = 42 hours in the laboratory.

Experimental determination of the efficiency of transformation of heat in steam to mechanical work, in steam turbines and reciprocating engines, and how it is affected by type of machine, characteristics of operation and conditions of initial pressure, back pressure and initial steam quality or superheat. Effect of cutoff, type of valve gear and piston speed on diagram factors of simple and compound engines; distribution of work and diagram factors in compound engines as affected by high pressure and low pressure cutoff and receiver size; effect of variation of cutoff on water rate of simple and compound engines; characteristics of steam flow as illustrated by orifice; venturi tubes, pitot tubes and commercial steam meters; power of steam jets as illustrated in the steam turbine, and experiments on steam nozzles and turbine blades.

39. *Gas Power:* Total time = 42 hours.

Use of gas-power equipment on natural gas, blast furnace, coke oven, and producer gas, gasolene distillate and heavy oil fuel as shown by statistics for manufacturing; transportation, railroad highway and water, and aeroplanes; mining, agricultural, pumping and central stations. Use of gas power as controlled by cost in competition with steam and water power, special adaptability to certain classes of service, prominence in small units and portability. System of operating gas engines, modern and historic, with analysis of reasons for abandonment of old systems. Fundamental thermal processes vs. mechanism to execute them, gas cycles and mechanisms of Brown, Wright, Barnett, Barsanti and Mateucci, Lenoir, Hugon, Otto and Langen, Atkinson, Otto, Brayton, Clerk, Diesel. Relation of indicator card to gas cycle form, and mean effective pressure, maximum pressures, specific displacement. Thermal efficiencies, cyclic and attained, diagram factors, equations for horsepower and efficiency of Otto and Diesel cycle engines in terms of compression, initial pressure, temperature, quality of fuel, air-fuel ratio, suction and exhaust resistances. Detailed analysis of Otto and Diesel engine losses from indicator card; suction line resistances and heating, volumetric efficiencies; compression line laws; combustion line vs. rate of propagation, piston speed, mixture, point of ignition or rate of fuel injection; expansion and exhaust lines, effects of valve timing. Mechanical efficiencies, piston speeds and horsepower. Properties of gaseous and liquid fuels and air-gas air-vapor mixtures, calorific value of mixtures; liquid fuel, liquid and vapor density, vapor pressure, air requirements, dew points of mixtures in combining proportions, fractional distillation and effect of overheating oils. Explosion pressures, heat suppression factors, temperatures of ignition, allowable compression, rates of propagation, limits of proportion for explosive combustion. Carburetors and vaporizers: humidifying and vacuum spray feed types. heat application, wetness. automatic carburetors, internal vaporizers. heaters for fuels and external air and mixture heaters. Gasolene and kerosene engines, high and low speed. forms for special classes of service. Heavy oil engines. hot-bulb and Franchetti delayed spray injection. Otto cycle compared with high compression Diesel cycle types. structural differences and performance effects. Gas producers for coke, charcoal and anthracite. special modifications for bituminous coal, pressure and suction operated shells, bed support, grates, blast introduction, gas take off. poking and agitating, coal feed and gas tight hoppers, blast humidifiers, water vaporizers. economizers, dust scrubbers. tar fixation and extraction. blowers: effect of form of structure, rate of gasification and kind of fuel on quality of gas. Modern gas engine structures, general arrangement. single acting. single and multi-cylinder, two and four cycle horizontal and vertical, double acting and tandem engines. frames, cylinders. liners. metal expansion control. heads. pistons, piston and tail rods. stuffing boxes, jackets and water supply, crossheads and water connections. valves, valve cages, springs, cams, rollers, pushrods and levers, valve gear systems, proportioning valves. gas pressure control valves, governing valves on cutout. quantity throttle and quality controls, governors. Ignition systems, make-and-break, jump spark, single and multiple dry and water cooled plugs and spark advance mechanism, sources of current. current distribution and transformation of voltage, magnetos. Starting systems. air and electric. muffling and exhaust piping. Gas engine regulation and balance, turning effort curves and determination of best number of cylinders. phase relations. weights of reciprocating parts and flywheels. Gas and oil engine installations. typical examples with cost and service analyses, fire underwriters' regulations on installation.

40. *Gas Power Laboratory:* 42 hours in the laboratory.

Experimental investigation of the properties of explosive mixtures of air and gas or vapor fuel, and the use of such mixtures in engines for producing power. Pressures and velocity of flame propagation of mixtures of varying proportions of gas and air; mixture making from gas fuels. mixing valves: mixture making from liquid fuels with and without external heating. carburetors and vaporizers; vapor-pressure-temperature characteristics of liquid fuels. Effect of variation of compression. point of ignition, back pressure. suction pressure, final jacket temperature and kind of fuel upon the mean effective pressure, volumetric efficiency, diagram factor, thermal efficiency and amount and distribution of heat losses in four cycle and two cycle internal combustion engines.

41. *Factory Construction and Equipment:* Total time = 140 hours, 56 class, 84 in drafting and computation room.

Factors governing the selection of site; types of building, single bay and monitor, multiple bays with and without side galleries and monitors, multiple floors, buildings for gravity processes, multiple bays with saw-tooth roof. Types of construction, timber, mill type, slow burning, steel frame, composite types, reinforced concrete. Foundations, bearing values of rocks and soil, timber and concrete piles, capping, grillages, bracing, sheathing of timber and steel, back tying in weak soils, footings, floor levels in relation to drainage and high water. Foundation walls, docks, wharfs, retaining wall pits. Floors, concrete, wood, stone, iron blocks, planks, brick, composite; stairways and protection, elevator shafts and enclosures; sash and casings, wood metal protected and all metal, plane plate and wired glass; trim, doors, wood, metal and underwriter construction. Side walls, brick, structural steel filled, corrugated metal, reinforced concrete, crane, beam and truss supports, plasters, openings, and limit of area bounded by walls. Partitions, timber, lath and plaster, fireproof tile and reinforced concrete fire walls, parapets, coping, casing of elevator walls and stairways, isolation of furnaces, cupolas and gas producers. Dead and wind loads, pressure and suction, live loads, vibrations and impacts. Roof trusses and framing, timber, steel and fireproofed steel; roof coverings, slag, gravel, tin, corrugated, steel, copper, iron, monel metal and special alloys, reinforced concrete, burned tile, glass, cement tile, asbestos, slate, drainage, monitors, louvres, skylights, ventilators. Requirements of fire underwriters and comparison of city building and state factory laws. Analysis of roof truss members and supports, columns, girders and beams, eccentrically loaded columns, portal constructure, crane runaways, tanks, bunkers, bins, chimneys, flues. Costs of construction, preparation of plans and specifications.

Selection of factory motive power, steam, purchased electric, gas engine and producer, gasolene and oil engine, water, shaft transmission. Electrical equipment, generators, transformers, motors, switchboards, system of current and wiring and connections for lights and motors. Selection and installation of shafting, pulleys, bearings, clutches and gears. Illumination by sunlight and lamps, ventilation, natural and forced; steam distribution for power, heat and drying; high and low pressure air systems for tools, lifts, heating and drying; low pressure vacuum systems for conveying factory waste and ashes with separators and exhausters; water distribution for fire and sanitary and press uses, water storage for condensers, manufacturing processes and fires, fire hydrants, sprinkler systems, other fire equipment for prevention and fighting fire; pumps, pipe lines and stations. Internal transportation of materials and product, continuous conveyors, belts, aprons, helical, flight, pan and bucket carriers, intermittent conveyors, cranes, overhead, jib, pillar and walking, hand, electric, air; locomotive, portal and gantry cranes, electric and steam, tubs, skips, buckets, magnets, ropes, fastenings, sheaves. Elevators, continuous bucket with belt and chains, steam and electric, with platforms and skips, steam, electric, air and shaft drive. Storage of bulk material by conveyors and cranes; small industrial railways, gauge, curves, tracks, switches, turntables, rolling stock, electric, air, gas engine and cable drives. Telephers. Auxiliary standard gauge railway equipment, interchangeable draw and running gears, locomotives, clearances. Overhead storage for gravity discharge of coal and bulk material in bins and tanks, outside storage, economic reserve and handling equipment.

Provision for first aid, hospital, wash, locker, reading, rest and living rooms, gate houses and fencing. Safety rules and devices for workmen.

42. *Manufacturing Process and Management:* Total time = 56 hours.

Distinction between manufacturing and construction or building, analysis of manufacturing industries by census, commission and trade reports; men employed, capital invested, value of raw material and increased value of finished product, power used, machines and processes of fabrication used, sources of raw material and markets for finished product. Location of plants and relation to raw material, markets, labor supply, transportation and banking facilities, power supply; geographical and topographical limits to location. Effect of the process itself and division of total into preliminary and finishing processes for different locations, illustrated by iron, copper, silver, zinc, sugar, textiles, leather, rubber, rope and oil. Comparison of transportation costs and rates for raw and finished product by railway, canal, river, lake and ocean carriers. Import and export duties. Processes compelling concentration illustrated by ship building, locomotive and car shops, engines and machine tools. Typical processes of typical industries analyzed and compared to bring out fundamental identity of principal elements, necessary machinery and methods with clear setting off of individual peculiarities of each, illustrated by iron and steel, locomotives and cars, ships, porcelains, earthenware, tile and brick, cement and plaster, lumber products including furniture, sugar, oil, glass, wire, rubber, brass and copper goods, pulp and paper, gas, central electric supply, cold storage and ice making, iron and steel products, hardware, tools, typewriters, stoves, electrical apparatus and machinery, printing presses, general machinery, agricultural implements. General treatment of division of processes into different buildings and relation analyzed on basis of routing of processes.

Cost a controlling factor in manufacturing operations, cost accounting systems and analysis of elements of cost of production, fixed charges, industrial labor and overhead. Methods of fixing labor and material costs and establishment charges. Use and interpretation of cost statistics. Value and depreciation of buildings, machinery, patterns and other costs. The balance sheet and annual report. Organizations based on processes, cost systems and other factors, true basis for type of organization found in analysis of functions to be performed by men employed and management based on efficient performance of each function with effective coöperation. Typical system of departmental organization and management. The departments of purchase, sale, manufacture and administration. Critical comparison of typical systems of organization and management with special reference to high efficiency and low costs.

PART II

REPORTS OF COMMITTEES

REPORT OF THE JOINT COMMITTEE ON ENGINEERING EDUCATION.

The original resolutions under which the Joint Committee on Engineering Education was appointed were passed at the Cleveland meeting in 1907. They are as follows:

WHEREAS, It is desirable to make a comprehensive study of the objects and the utilities and the correct ideals of engineering education; therefore be it

Resolved, That the Society for the Promotion of Engineering Education hereby invite the respective governing boards of The American Society of Civil Engineers, The American Society of Mechanical Engineers, The American Institute of Electrical Engineers and The American Chemical Society, each to appoint two members to become delegates composing part of a joint committee on engineering education, which committee shall consist of the said two members appointed from each of the aforesaid societies, or the delegates from such societies as accept this invitation and appoint their respective delegates, and three members appointed as delegates by the Society for the Promotion of Engineering Education; and in pursuance thereof be it further

Resolved, That the council of the Society for the Promotion of Engineering Education is hereby directed to appoint three members as delegates to the membership of the said joint committee on engineering education; and be it further

Resolved, That the duty of the said joint committee shall be to examine into all branches of engineering education, including engineering research, graduate professional courses, undergraduate engineering instruction, and the proper relations of engineering schools to secondary industrial schools, or foremen's schools; and to formulate a report or reports upon the appropriate scope of engineering education and the degree of cooperation and unity that may be advantageously arranged between the various engineering schools."

The resolutions further state that the joint committee is requested to make a report of progress to this society within a year, and to make its final report to this society within two years.

At the Detroit meeting in 1908 a resolution was passed authorizing this committee to invite the Carnegie Foundation for the Advancement of Teaching and the General Education Board to appoint delegates.

During the intervening year the time was taken up in organizing the joint committee. This was a difficult matter as the great engineering bodies are bound by the detailed provisions of their respective constitutions. Each, however, met the situation in an admirable spirit. and the committee was duly appointed. The several societies appointed distinguished members who were in touch with the educational movements of the day, a number being past presidents of their respective Societies.

After eighteen months had been used in organizing the committee, a number of meetings were held and the work before it was canvassed. The actual work began with a study of the catalogues of the various engineering schools from which it was found after two attempts, to be impossible to obtain the desired information. The American Society of Civil Engineers then made an appropriation to see if the study could be carried farther with profit, but it was again found to be utterly impracticable to obtain an adequate idea of the accomplishments and purposes of engineering schools from their catalogues. The committee thereupon invited the Carnegie Foundation for the Advancement of Teaching to undertake an investigation which it was estimated would cost ten thousand dollars. It seemed necessary that properly equipped agents should visit the engineering schools throughout the land, and after investigating these, should study the relations between the engineering schools and the engineering professions. At that time the Carnegie Foundation for the Advancement of Teaching was engaged upon a study of medical education, and was hardly in a position to incur the necessary expense for this one. Fortunately Mr. Carnegie came to the rescue by increasing the endowment and the Foundation has now taken up the study and appointed an agent. The agent appointed, Dr. C. R. Mann, is not an engineer, but he was trained in physics, a closely allied subject. It is expected that he will make a full and complete investigation and draw up an analytical report.

As the committee's work has progressed we find that there is greater unity of ideals and fewer fundamental differences of opinion than appeared to exist at the time of our first meetings. We are optimistic with respect to the ultimate outcome of the work of this committee. Eventually we hope to have a report which will be of great value to the cause of engineering education.

In the organization of the Joint Committee, Mr. Desmond FitzGerald (A.S.C.E.) was made Chairman, and Dr. Samuel Sheldon (A.I.E.E.) was made Secretary. The representatives of this society wish to express their recognition of the able work of these officers.

Gardner C. Anthony,
Charles L. Crandall,
Dugald C. Jackson,
S. P. E. E., Representatives on the Joint
Committee on Engineering Education.

REPORT OF THE COMMITTEE ON COLLEGE ADMINISTRATION.*

The object of this report is to present an outline of administration in engineering colleges as it exists today with the hope that it will arouse interest and discussion in this important feature of education.

The increase in wealth and size of American colleges and universities has caused the administrative department to become more and more important. This development was to be expected when we consider that the college is usually controlled by a body of men, the trustees, whose time is largely devoted to administrative work in business. However, there has been comparatively little discussion and no special attempt to outline the duties of the various members of the college as an organization.

In American business organizations the functions of the various departments, such as operating, engineering, purchasing, selling, etc., are clearly defined. These are practically duplicated in departments of all corporations conducting the same kind of business. If the functions of the different departments of an organization in the business world can be so clearly defined, we in the educational world should be able to define the departments of our work even more clearly.

The college organization consists essentially of three departments: financial, administrative and teaching. The present report deals with the first two of these departments.

Financial Department.

The financial department has charge of the following: The care of all property of the institution; the transaction of all general business assigned to it by the board of trustees; the purchasing of all equipment and material; the keeping of all accounts with the specific duty of keeping all expenditures within the budget and the paying of all bills, and general supervision during the erection of all new buildings and additions.

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* See S. P. E. E. Bulletin, Vol. IV, p. 701, for preliminary report presented at the Minneapolis Meeting.

This department has no control over expenditures except to see that the funds are expended in accordance with the actions of the board. This arrangement concentrates the purchasing power in one officer who should be chosen with great care, if the institution is to receive value for money expended. Such an arrangement relieves the college professor of a large amount of detail work for which he is not especially fitted. It is true that when special equipment is being purchased, the correspondence should be carried on by the head of the department in which the equipment is to be placed. However, as soon as the exact type of equipment has been selected all details of ordering, shipping, delivery, etc., should be left to the purchasing agent. The importance of this department to every member of the faculty becomes evident when we consider the case of a single institution whose annual expenditures approximate $4,000,000. A good purchasing agent will save the time of many professors and should save the institution employing him more than one professor's salary.

Administrative Department.

The administrative department in colleges should remove from the members of the faculty the petty details of operation and administration, leaving them free to devote their time to teaching investigating and productive scholarship. It should assist by providing adequate facilities, properly prepared students, freedom from interruption, etc., and above all should surround the faculty with the proper "atmosphere" for its work. The fundamental object of the department is to increase the efficiency of the teacher in order that the student may secure the maximum benefit from his course.

The most effective type of organization is that in which the administration is least in evidence. This department can be compared to the engine of an automobile. The latter should have sufficient power to carry the car and its passengers not only over smooth roads but through rough and hilly districts. It should do its work without noise or attention from the passengers. It is an important part of the car but it should cause the least worry and require a minimum of attention.

The department of administration includes the president, the registrar, and the deans.

The president is the chief executive officer. His duties are many and varied. He is chairman of the faculty, and as such should be the leader and to a considerable extent the originator of the educational policies of the institution. He is often given extraordinary power by the board of trustees over the financial policy of the institution. He selects and recommends to the board upon recommendation of the deans, all members of the teaching staff. He is the representative and spokesman of the institution upon public occasions. His numerous other duties are so comprehensive that they could not be included within the present report.

The duties of the registrar are fairly well defined. They consist in keeping a complete record of all students.

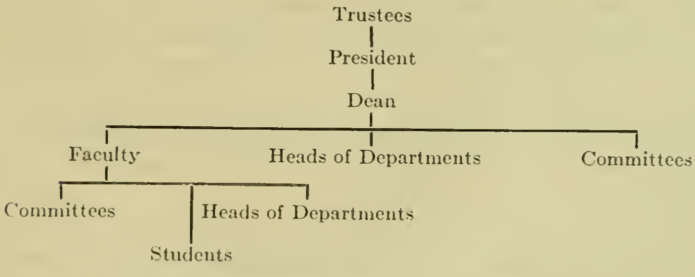
The functions of the dean of a college of engineering were very ably described by Deans Turneaure and White at the Cleveland meeting in 1907. Since that time the duties of the dean have become better defined owing to the necessity of providing a better administration in engineering schools than formerly existed.

The dean is the executive officer of the school in all educational and business relations and is in these matters responsible only to the president. The annual budget in regard to all appropriations is prepared by the dean in consultation with, and upon recommendation of, the heads of departments.

The most important function of the dean is the assigning of work and the general supervision of the students. This is of course carried on under regulations of the faculty and much of the supervision should be done by the heads of the departments, after the student has selected his course. The dean is the students' personal representative before the faculty. He must assure the student a "square deal" at all times, always being fair to both the student and the faculty, while giving the former the benefit of the doubt.

Some institutions have adopted a system of student advisorship which in certain cases is satisfactory, but in general the student, especially during his first two years, wishes to have the opportunity of talking directly with the head of the school. Later he appreciates the opportunity of consulting freely with the head of the department in which most of his work is done.

One of the important duties of the dean is to attend the meetings and conferences of educational and engineering societies. The increasing number of deans who attend meetings of this society emphasize this point. He must in addition to the rest of his work, do some teaching or he will eventually lose touch, and thus lack sympathy, with the teaching profession.



The dean must develop that *esprit de corps* especially among the younger men of the faculty, without which no school or other institution can be successful. He must create the general policy of the school with regard to expansion, creation of new departments, enlargement of existing departments, etc.

The dean is a member of both the administrative and teaching departments. A large part of the executive work of the teaching department, not done by the dean, is assigned to committees of the faculty appointed either by the dean or by the faculty as a whole. The relation of the dean to the faculty is shown by the following diagram:

A committee makes studies of various problems which arise and reports the results either to the faculty or to the dean, depending upon who creates the committee. It has no powers except those specifically delegated to it when it was appointed. A very large part of most committee work should be done in the administrative offices and in consultation with members of the faculty.

Standing committees do not differ from other committees either in their functions or duties. They are in fact like all committees except that they are appointed for a longer time and to consider problems usually of the same character which arise periodically. The following list of the standing committees of a few engineering colleges shows a wide variation.

Massachusetts Institute of Technology; committees on faculty business, courses of instruction, petitions, unclassified students, five-year courses, provisional students, foreign students, military exercise, summer courses, summer reading, graduation exercises, recommendation of graduates for appointments, advanced degrees of fellowships, undergraduate scholarships, and publications.

Stevens Institute of Technology; committees on scholarship and discipline, curriculum, entrance examinations, athletics, commencement, roster and library.

Pennsylvania State College; executive committee, advisory committee, and committee on delinquencies and deficiencies, entrance requirements and examinations, graduation requirements, graduate study and advanced degrees, physical activities, public occasions, religious occasions, scholarships and prizes, and student publications and social functions.

Case School of Applied Science; committees on absences, entrance requirements and examination, courses of study, athletics, practice term, accredited schools, graduate and irregular students, higher degrees, grounds and buildings, and assemblies and lectures, and student advisory committee.

Since engineering schools are so much alike in the work which they do, a certain number of standing committees should be common to all schools. Each school would probably have one or more other standing committees which arise from local conditions.

Many of these committees do work which should be done by clerks in the administrative offices. This use of a member of the faculty as a clerk is a weakness of American colleges. A prominent engineer and scientific man, the head of a department in a large engineering school, when introduced at an alumni gathering as the head of the department, stated that this really was an error, as he was to all intents and purposes the chief clerk of the department. This condition exists throughout that school and in many others. It arises partially from an apparent unwillingness on the part of members of the college faculty to transmit their authority to subordinates. It is impossible and undesirable to relieve members of the teaching staff from all executive work, but it certainly is unwise to have the highest salaried men doing poorly the work which trained clerks could do much better at a fifth of the cost. It does not make an institution democratic to have its professors copy class rolls, list of grades, etc., or to write letters and requisitions in longhand.

The head of a department is responsible for the work in this department, both as regards general administration and teaching.

He should have absolute power in regard to recommendations concerning appointments and removals of members of his staff. The department through its head is in a general way responsible for all students taking its particular courses. If the head of the department, in consultation with the members of his staff, believes that a student should pursue some other branch of engineering study or some other entirely different educational activity, that student should be transferred by the dean to another department of the school. The professor must be familiar with the modern trend of engineering, especially in his own profession, and consequently more or less of his time must be spent in consulting engineering practice. The head of a department is perhaps the most important factor in the student's education. It is largely through his originality, and persistence in the selection of the men and apparatus that the student under him will be properly prepared to become an engineer. He should select apparatus which will assist in instruction as well as in carrying on original research. No man should be at the head of a department who will use all the funds assigned to him in the purchase of apparatus for his own pet researches or will use his assistants in such work, or who will appoint only his own graduates to positions in his department. It is to avoid such abuses that it is necessary for the dean to have veto power over the actions of the heads of the departments. It is not necessary to have called to our attention the institution in which more than thirty members of the instructing staff of a single department were graduates from that department. The department was 100 per cent. inbred. It was without supervision except through its head.

The greater the ability of the individual members of a department, the better it is for the college. If, however, the work of these men is not properly coördinated, the school soon graduates men who are one-sided. This has become a familiar and almost accepted phenomenon of American engineering colleges.

REPORT OF THE COMMITTEE ON STATISTICS OF ENGINEERING EDUCATION.

BY ARTHUR J. WOOD, Chairman,
Associate Professor of Mechanical Engineering, Pennsylvania State College.

At the Minneapolis meeting of the Society, Professors F. A. Barnes, Cornell University, J. D. Phillips, University of Wisconsin, F. A. Fish, Iowa State College, H. H. Stock, University of Illinois, and A. J. Wood, The Pennsylvania State College, were appointed on the standing committee to gather and to report on statistics of engineering education. The work of the committee during the past year has covered primarily a study of the entire field including a consideration of the kinds of statistics which should prove to be of permanent value. This, in a word, would describe the work of the committee as a whole.

The valuable reports of the previous committee on statistics, made by its chairman, Professor W. T. Magruder, may be found in the *Proceedings* of the Society. The data presented have had an important place in the effective work of this organization.

Our committee, through its chairman, recently took up the matter of attendance at engineering schools. From the report made last year by the committee on college administration covering this subject, it appears that the attendance at fifty-five engineering schools reached a maximum about 1909 and since then it has gradually been falling off. Continuing the work of that committee, we find that in May, 1914, there were 24,740 undergraduates, postgraduates and special students taking courses leading to engineering degrees in sixty-nine institutions, which is an average of 358 in each. Of this total number 23,518 were undergraduates, and 4,198 were undergraduate seniors.

In so far as information has been received, the attendance in these schools was as follows:

In departments of civil engineering 4,840; mechanical engineering, 4,553; electrical engineering, 4,331; mining engineering, 1,065; other departments, 3,136, of which 918 were in engineering courses in chemistry. In addition, among the unclassified, are students in architecture, and architectural engineering.

The following institutions have over 600 students each, enrolled in engineering courses, arranged in the order of attendance: Massachusetts Institute of Technology; Cornell University; University of Michigan; Yale University; Purdue University; University of Illinois; The Pennsylvania State College; University of Pennsylvania; Ohio State University; University of California; University of Wisconsin; Columbia University; Iowa State College; Rensselaer Polytechnic Institute.

The following table shows the distribution of engineering students in 1913–14 among seventy colleges.

0–50	engineering students	in	3	institutions.
51–100	engineering students	in	13	institutions.
101–200	engineering students	in	11	institutions.
201–300	engineering students	in	15	institutions.
301–400	engineering students	in	3	institutions.
401–500	engineering students	in	11	institutions.
501–1000	engineering students	in	8	institutions.
Over 1000	engineering students	in	6	institutions.

A study has been made to determine the attendance in 1914 compared with the attendance in 1913. In thirty-two institutions where accurate returns are available for both years, twenty-one show an increase of 1,381 students, while eleven of the thirty-two show a decrease of 340 students. The total in attendance in these thirty-two institutions during 1914 was 13,618, and in 1913 the corresponding number for these same institutions was 12,577, showing a gain of 1,041 or 8.3 per cent. Referring to the report presented at the Minneapolis meeting last year, fifty-five engineering schools had an attendance of about 14,000. From the above, it appears that the attendance curve as plotted (see BULLETIN of the Society for November, 1913) has changed from its downward course to an upward trend. In a word, the attendance is better than it has been for some years.

The committee has also considered certain subjects on which there is limited or no information available. In order to have accurate data before it the committee sent a questionnaire to the same 106 institutions which were asked to give attendance statistics.

The questions and a summary of the answers follow:

1*a*. Does your institution require summer work in the industries as a part of the regular course? Answers: "Yes," 11; "No," 28; "In part or occasionally," 18.

1*b*. Is summer experience accepted in lieu of regularly scheduled subjects? Answers: "Yes," 10; "No," 28; "In part or occasionally," 18.

1*c*. If so, principally in what subjects? Answers: Shop, 12; surveying and field work, 9; drafting, 6; civil engineering, 1; mining and mineralogy, 2.

2*a*. Do you find that students who spend their summers in industrial employment have a higher wage earning value on graduation? Answers: "Yes," 29; "No," 4; "Occasionally," 11.

2*b*. Does summer employment tend to better the scholarship of students? Answers: "Yes," 37; "No," 4; "Not materially or questionable," 8.

3*a*. In your opinion, is the average pay to engineering graduates during the first year out of college too low? Answers: "Yes," 13; "No," 31; "In some cases," 5.

3*b*. What would you estimate the average pay to be? Answers: Range $40.00 to $100.00; average $68.00.

3*c*. What suggestion for betterment can you make? From the many replies in answer to this question, the following may be here noted:

"Companies should devote more time finding out what each individual could do." "Prepare men to be worth more." "Weeding out the lazy, indifferent and ill-fitted and improve quality delivered." "More English and other language work." "Every undergraduate should be required to spend summers in industrial employment." "Unless employers recognize the value of technical training, the supply of good men will not equal the demand." "A higher standard in the industries." "A better appreciation of the things that a college graduate should be able to do well and an insistent demand that he do them." "Companies do not discriminate between students of different ability." "More interest in government and politics." "More thorough training in reasoning powers and teaching self-reliance."

4*a*. Give estimated percentage of students in attendance 48 hours before Christmas and Easter vacations. Answers ranged from 40 per cent. to 100 per cent., average 92; attendance above 90 per cent., 48; attendance below 90 per cent., 4.

4*b*. The same for 48 hours after vacations. Answers: The same as those for the preceding question.

4*c*. What means have been found most effective in securing a high percentage attendance at such periods? Answers: Twenty-seven methods have been proposed and these may be grouped as follows:

Unjustifiable and unexplained absence = 0	5
Cut counts double	5
Fines for late registration	5
Absence at this time count as cuts with special penalty of $5.00 for examination	3

The other methods included personally presented excuses from the President; enforced military system; deduction on final term grade; ten per cent. absent rule; dormitory system and personal warning.

It would appear from the above that equally desirable results are obtained from widely different methods.

A condensed summary of the replies would indicate the following: Required summer work in the industries is favored or required in about 50 per cent. of the institutions reporting. Such work is not usually accepted in lieu of regularly scheduled subjects. Students who spend their summers thus employed are believed to rank higher in scholarship and to have a higher wage-earning value on completing their courses at college.

The impression strongly prevails that the average pay to engineering graduates during the first year out of college is not too low. Out of forty-nine replies, thirteen were emphatic in stating that it is too low. Except in few cases, the attendance immediately before and after Christmas and Easter vacations is nearly as good as it is during the other periods in the semester. However, we should not lose sight of the fact that there are no less than twenty-seven different methods followed to accomplish this result. It is quite evident that too much weight should not be given to the individual method to secure a desired end.

In the case of suggestions for betterment of the output of our engineering schools in order that they may have a higher wage-earning value, let us not lose sight of the fact that we are facing a commercially vital problem and the replies indicate that unless employers coöperate, we may not hope for any decided betterment. The viewpoints of the two interests concerned should be in substantial agreement on the main issues of engineering education, for otherwise we may compromise true educational standards for purely a wage-earning product.

Individual members of the committee have undertaken special investigations on the following subjects.

1. The amount of drafting done in practice by graduates during the first few years after graduation from college.

2. The true value of required summer school work in the industries.

3. The number of students for each instructor in electrical engineering in representative institutions.

It is not possible at this time to submit a report on the results of this work.

Reference may be made to the data compiled by Professor J. E. Kaulfuss, University of Maine, who has obtained and analyzed much information on three important subjects;

namely, inspection trips, summer work, and summer reading. In a word, he finds that inspection trips are generally favored, forty-seven out of sixty-nine requiring them to be taken, and the replies speak uniformly in favor of their success.

Summer work at colleges is generally favored and rarely are substitutes allowed for this work. Very few colleges are requiring summer or term time reading.

A. J. Wood, *Chairman,*
F. A. Barnes,
F. A. Fish,
J. D. Philips,
H. H. Stoek,
Committee.

REPORT OF THE COMMITTEE ON COOPERATION IN ELECTRICAL ENGINEERING INSTRUCTION.

This committee was appointed two years ago. At the convention one year ago, a report was made giving a list of topics suggested by various members of the committee as suitable for suggestion or comment by the members of the Society, replies, presumably, to appear in the monthly BULLETIN.

No specific instructions or methods of procedure have been given to the committee, and it has not initiated any of its own. Members of the committee have, however, recently presented a number of suggestions of suitable topics for consideration which may be summarized as follows:

1. The essential equipment for a dynamo laboratory.
2. The essential experiments and equipment for an electrical measurement laboratory course.
3. The essentials for a course for non-electrical engineering students.
4. The desirability of a more detailed study of the personal qualifications and training of students.
5. The advisability of further training in organization, management and regulation of public service utilities, either for all students, or only for those particularly fitted for commercial or executive positions.
6. Progress in the design and construction of electrical laboratories as typified by the developments of the year.
7. Arrangement of apparatus in electrical laboratories to facilitate instruction.
8. Electrical laboratory switchboards.
9. Facilities for research in various electrical laboratories of the country.
10. The subdivision of the work of the committee, giving each section a definite field for investigation.

11. The issuing of printed lists of questions under the authority of the committee to recognized departments of electrical engineering and to the testing departments in various companies, relative to certain of the foregoing topics.

In the way of definite suggestion and recommendation, the following is set forth:

1. There is need of work along the lines contemplated when this committee was appointed.

2. Definite divisions of the work of the committee should be assigned to the individual members. In general, before carrying out specific methods or issuing circular letters, the committee should be consulted by correspondence for suggestion and sanction.

3. The material collected should, in general, pass through the chairman of the committee and, as far as practicable, it should appear in the PROCEEDINGS.

4. The bringing out, and stating of the various problems and topics in which electrical teachers are interested may lead to communications or papers on these subjects for publication in the BULLETIN which may be communicated directly to the secretary, thus supplementing the specialized efforts of the committee itself.

C. F. SCOTT, *Chairman.*
W. I. SLICHTER,
C. F. HARDING,
H. H. NORRIS,
G. B. THOMAS.

DISCUSSION.

Professor V. Karapetoff: I have two problems which confront me in the electrical laboratory instruction.

The first problem is: "Shall the *quantity* of work be considered as being of paramount importance, or is it the *thoroughness* with which problems are investigated in the laboratory?" This is one of the fundamental questions in planning laboratory instruction. There are a certain number of fundamental types of electrical machinery, such as direct-current and alternating-current generators and motors, rotary converters, etc. Each student may be required to devote, say, six hours to an exercise with each of these, in order that, when he graduates, he may be able to say that he handled each type once. Or else, a group of students may be allowed to devote five or six weeks of work to a particular type of machine, or until they have satisfied themselves and the instructor that they understand it. If they do this, they may have to entirely disregard other types of machinery, equally important in practice. The teacher then proceeds on the assumption that, having investigated one, they can investigate other types of machinery with little difficulty. I should like to know which method is the best in the end.

The other problem is that of laboratory reports. As Dr. Kent has said, it is very difficult to estimate how much time an average student will require for a report. After all, who is an average student? We hear the complaint that certain professors appropriate time belonging to other subjects by specifying an unreasonable number of requirements in their reports. I hope the committee will elucidate this subject, and will suggest how just requirements in regard to reports may be determined. We are trying to meet the situation by dividing the requirements for an experiment and for the report into two parts, the required part and the optional part. The required part is reduced to a minimum, with the expectation that any student can complete it within reasonable time. Even the student who is markedly deficient gets through with the required part, but he receives only a mark of 65 or 70 per cent., and in some cases only 50 per cent. for the required part. A definite percentage is added for satisfactory completion of each option. If we specify (say) four options in addition to the required part, we mark the latter on the basis of 60 per cent., and give twenty points for each of the two options satisfactorily completed.

There are several arguments in favor of these options. In the first place, they allow some play for the natural ability ot the student, as we select the options so as to have some of them of a commercial nature, others of a mechanical nature, while a few require mathematical analysis, plotting of curves, or drafting of machinery. Then again, a student temporarily overloaded with work may drop the options and be satisfied with a mark of 60. The system of options equalizes the effort and diversifies the work.

Professor E. J. Berg: While it may seem desirable to standardize the experiments in electrical engineering laboratories as well as in other engineering laboratories, I doubt whether it is possible to do so until we standardize the course of instruction, which I hope will never be the case. One institution lays stress on the practical side, another on the theoretical side; and, since the experiments should be correlated with the instruction, the amount and the nature of the experiments must be determined by the instructions given.

At the University of Illinois and at Union College one third of the time devoted to electrical engineering instruction is taken up with the fundamental principles of electric and magnetic circuits, another third with the transformer, a very simple piece of apparatus, and the last third with the rest of the apparatus and transient phenomena. We make relatively few experiments, but these very thoroughly, and the experiments are rarely standard. For example, in experiments on transformers we require in addition to the usual experiments, calculations and experimental work to determine the mechanical stress in the windings.

Professor D. C. Jackson: I recognize the thoroughness with which Dr. Berg has been analyzing the problem of the electrical laboratory of the engineering schools. But after all, the problem appears to me to be different from that which he stated. The problem is one of choosing between what may be called a prearranged plan with scheduled apparatus and predigested teaching by instructors on the other hand, and a method of putting the students into the laboratory for the purpose of arriving at results on their own accord. I dislike predigested matter, and prefer accomplishment by the student. As far as specific experiments are concerned, however, there are certain fundamental principles of electricity and magnetism which the student must become familiar with in the laboratory, because it is here that the teacher can lead him "to do and dare" in the application of the principles learned in the classroom. If he was properly trained in the mathematical principles, he should be able to attack a laboratory problem intelligently.

The stationary transformer furnishes a wide range of experiment for the student. So there are many types of machines upon which alternative experiments can be taken up by different students and which illustrate the same specific principles. One can, in laboratory work, give the students a sound knowledge and a firm grasp of electrical engineering, although no two students need perform exactly the same experiments. But you can be sure every conscientious student in the class knows what the others have done, and he has gained in accomplishment much more than he would have done by carrying on a specified, predetermined set of experiments.

REPORT OF THE COMMITTEE ON COÖPERATION IN CIVIL ENGINEERING LABORATORY INSTRUCTION.

Under date of February 27, 1913, the chairman of your committee addressed a letter of inquiry to a selected list of twenty-three institutions and of this number more or less complete replies have been received from seventeen. In the Bulletin dated December, 1913, the same letter of inquiry was published and in response thereto two universities sent answers to the questions asked.

The arrangement and manner of conducting courses at some of the institutions differ so widely that it has been difficult to accurately classify the replies. It is hoped, however, that the information received has not been misinterpreted. In studying the data shown it should be borne in mind that in many cases laboratory work is so closely allied to class-room instruction that it is difficult to reach a conclusion regarding the one unless complete data of the other be at hand. Nevertheless the tabulations herein given afford a comparison between the laboratory practices of the institutions shown.

The purpose of the committee in accumulating the information has been to ascertain the kind and amount of instruction given in laboratories to civil engineering students only.

The questions about laboratory practice submitted by the committee are grouped under the following headings:

1. General laboratory practice.
2. Materials testing laboratory.
3. Hydraulic laboratory.
4. Cement laboratory.
5. Road materials laboratory.

General Laboratory Practice.

Table I shows that practice generally sanctions the three-hour period for the materials, hydraulic and cement labora-

TABLE I.

Giving Summary of Answers to List of Questions Regarding Laboratory Practice.

	1				2	3	4	5	6	7			
Name of Institution.	Number of Hours Scheduled per Week.				Do Scheduled Hours Include Test Only, or Time for Writing Reports as Well?	Do Students Write Reports at Home or Under an Instructor?	What Preliminary Study is Required? How Do You Insure that Study is Done?	Is it Desirable to Have Students Read References and Submit Written Report Before Making Tests?	Does Class-work Precede or Parallel the Laboratory Work? Which is Better?	Fees Charged.			
	Materials.	Hydraulic.	Cement.	Roads.						Materials.	Hydraulic.	Cement.	Road Lab.
Armour Inst. Tech.	3	3	3	0	Lab. only	At home	Lectures, reading, references, and reports	Yes	Given parallel or a week in advance	.....	.....	.....	.....
Carnegie Inst. Tech.	3	3	3	0	Two hrs. lab. One hour report	At home	Recitations in advance. No references	Not good practice	Parallel, the better method	0	0	0	0
Cornell University	3	0	3	0	Lab. only	At home	Nothing required	"Absolutely bad practice"	Parallel, the better method	75c credit hour			
Harvard University	3	3	3	3	Lab. only	At home	Lectures and reading references	Opinions vary as to value	Parallel, the better method	Fees are charged by courses			
College of Hawaii	6	..	3	...	Lab. only	At home	Nothing required	Reading but not preliminary reports	Parallel	$1.50	.....	$1.50	.....
Illinois, Univ. of	2	2	2	0	Lab. only	At home	Read manual in advance. No references	Reading but not preliminary reports	Parallel, if possible	$2.00	$1.00	$1.50	.....
Iowa, State Univ. of	?	3	?	0	Lab. only	With instructor	Nothing required	Yes to some extent. No preliminary report	Parallel, the better method	0	0	0	0

TABLE I—*Continued.*

Name of Institution.	1				2	3	4	5	6	7			
	Number of Hours Scheduled per Week.				Do Scheduled Hours Include Test Only, or Time for Writing Reports as Well?	Do Students Write Reports at Home or Under an Instructor?	What Preliminary Study is Required? How Do You Insure that Study is Done?	Is It Desirable to Have Students Read References and Submit Written Report Before Making Tests?	Does Class-work Precede or Parallel the Laboratory Work? Which is Better?	Fees Charged.			
	Materials.	Hydraulic.	Cement.	Roads.						Materials.	Hydraulic.	Cement.	Road Lab.
Iowa State College	3	3	3	3 elective	Hydraulic and materials test only. Cement 2 hrs. lab. and 1 hr. report	With instructor	30 min. usually allowed for preliminary work	Doubtful value	Cement, parallel, others, lab. follows	$3.00	$3.00	$3.00	$3.00
Kansas, Univ. of	3	2	2	0	Materials—lab. and report. Others—lab. only	Mat. with instructor Others at home	Preliminary study is sometimes required	Yes—generally	Parallel, the better method	$1.50	$1.00	$1.00	0
Lehigh University	3	3	3	0	Lab. only	At home	References assigned	References good, but preliminary reports not good	Parallel, the better method	$5.00	$5.00	$3.00	0
Maine, Univ. of	2	2	2	1	Lab. only	At home	Preliminary reports in materials and hydraulics. Cement and roads, nothing required	Yes	Parallel, generally	$2.00 to $4.00			
McGill University	3	3	3	0	Lab. only, generally	At home	Nothing required	Generally,—No	Both methods followed	.....	.....	.....	.....

TABLE I—*Continued.*

Name of Institution.	1 Number of Hours Scheduled per Week. Materials.	Hydraulic.	Cement.	Roads.	2 Do Scheduled Hours Include Test Only, or Time for Writing Reports as Well?:	3 Do Students Write Reports at Home or Under an Instructor?	4 What Preliminary Study is Required? How Do You Insure that Study is Done?	5 Is it Desirable to Have Students Read References and Submit Written Report Before Making Tests?	6 Does Class-work Precede or Parallel the Laboratory Work? Which is Better?	7 Fees Charged. Materials.	Hydraulic.	Cement.	Road Lab.
Michigan, Univ. of	3–4	0	3–4	0	Lab. only	At home	Sometimes required to study reports	Yes	Class room work precedes	0	0	0	0
Missouri, Univ. of	2	0	2	Elective 2	Lab. only	At home	Nothing required	No advantage in the practice	Parallel, but lab. is better if class precedes	$5.00	.....	$5.00	$5.00
Ohio State University	4	?	3	......	Include both	Final write-up at home	Nothing required	No	Class room work precedes lab. work	75c per credit hour per student			
Penna. State College	2	2	2	4 Jun. 2 Sen.	Include both	With instructor	Nothing required	Yes	Parallel in some cases, better if class first	$2.28	0	$1.00	$3.00 $2.00
Penna., Univ. of	3	3	3	......	Lab. only	At home	Preliminary reports in materials and cement. Hydraulic, nothing required	Yes	Partly parallel	Nominal	.....	.....	.....
Washington, Univ. of	4	3	2	3	Include both	Largely with instructor	Nothing required	Reading—Yes Reports—No	Parallel	$2.00	.....	$1.00	.....
Wisconsin, Univ. of	3	4	3	0	Materials Cement } Lab. only Hydraulic—both	Materials Cement } at home Hydraulic—in lab.	Nothing required	Materials Cement } No Hydraulic, yes	Materials Cement } Parallel Hydraulic, lab. follows	$6.00	$2.00	$2.00	0

tory exercises. In some schools the time scheduled is two hours and in one of these instances the period is expected to cover not only experimental work but preparation of report as well. Generally speaking, however, the three-hour period scheduled is devoted entirely to experimental work and the student is expected to prepare his report outside of assigned hours and in most cases without the supervision of an instructor.

The testing of road materials is given in so few schools that it is difficult to draw conclusions pertaining thereto.

This question of number of clock-hours devoted to one exercise per week is an important one because it indicates that students spend considerably more than three clock-hours for one term-hour credit. This is particularly important in courses in civil engineering where students may have not only the civil engineering laboratory work but also work in electrical and perhaps physics laboratories during the same week. If a student spends three clock-hours in a laboratory exercise and three clock-hours at home writing his report his six clock-hours of work per week should entitle him to more than one credit hour.

In the majority of institutions no preliminary study relating to a particular exercise is required in advance of the laboratory experiment. Practice varies in the remaining institutions; the study of reports presumably selected from outside sources, reading references, and lectures being variously specified. Although asked for, no solution of the problem of how to insure that the student actually performs this work in advance is submitted, except that two institutions require preliminary reports in some laboratory work. It is presumed that these preliminary reports are written by students to show that they have read the assignments in preparation for the laboratory experiments.

Opinions vary widely regarding the question of whether or not it is desirable to require this preliminary study and the handing in of reports in advance of experimental work; a few replies are in the affirmative, a few in the negative and one characterizes it as "absolutely bad practice." It is prob-

TABLE II.

Giving Summary of Answers to List of Questions Regarding Materials Testing Laboratories.

Name of Institution.	1 Number of Exercises per Year.	2 Are Blank Forms Provided?	3 Is Shearing Deflection Considered in Comparing Computed and Observed Center Deflection of Beams?	4 Have You Used Mirror Extensometers? Are They Satisfactory?	5 Are Vibratory or Impact Tests Given to Undergraduates?	6 Are the Tests of No. 5 of Value to Undergraduates?	7 What Machines and Methods Are Used in Torsion Test?	8 Give Any New or Unusual Tests You Assign to Undergraduates.	9 Have You Any New Device for Reading Deformations?
Armour Inst. Tech	5	Yes	No	"Home-made" Bauschinger	No	No	Olsen 4,000 ft. lb. and Thurston autographic	None	Burnham Extensometer
Carnegie Inst. Tech.	17 junior	No	No	No	Impact only	Yes	Amsler-Laffon 1,000 ft. lbs.	Impact test	No
Cornell University.	16 sophomore	Yes	Sometimes	Yes, very satisfactory	No	Not for sophomores	....	None for sophomores	Yes
Harvard University	10	No	Advanced work only	Yes, very satisfactory	Yes	Of moderate value	None	Tests of riveted joints	No
College of Hawaii	34 junior	Yes	No	No	No	No	Olsen 50,000 in. lb.	None	No
Illinois, Univ. of	16 junior	No	No	No	Yes. On wooden beams	Yes	Riehle 10,000 in. lb. Olsen 230,000 in. lb.	Comparison of static, sudden and impact loading	Not for regular classes
Iowa, State Univ. of	5 junior	No	Not measured	No	No	No	None	None	No
Iowa State College	9 junior	Yes	No	No	No	....	60,000 in. lb. Olsen torsion mach.	Tile and sewer pipe	....
Kansas, Univ. of	15 junior	Yes	No	No	No	No	Olsen 25,000 in. lb.	None	Extensometer

TABLE II—*Continued.*

	1	2	3	4	5	6	7	8	9
Name of Institution.	Number of Exercises per Year.	Are Blank Forms Provided?	Is Shearing Deflection Considered in Comparing Computed and Observed Center Deflection of Beams?	Have You Used Mirror Entensometers? Are They Satisfactory?	Are Vibratory or Impact Tests Given to Undergraduates?	Are the Tests of No. 5 of Value to Undergraduates?	What Machines and Methods Are Used in Torsion Test?	Give Any New or Unusual Tests You Assign to Undergraduates.	Have You Any New Device for Reading Deformations?
Lehigh University	14 junior	Yes	No	No	No	No	Olsen 24,000 in. lb.	None	No
Maine, Univ. of	14 junior	Yes	No	No	No	No	Amsler 1,200 in. lb.	None	No
McGill University	12 junior	No	No	Yes, satisfactory	Tests of springs. No impact	No	Lever machine	None	No
Michigan, Univ. of	Junior or senior	No	Sometimes	In special research. Yes	No	No	Olsen 230,000 in. lb.	None	No
Missouri, Univ. of	22 1st and 2d yrs. of three-yr. course	To some extent	No	No	No	No	Olsen 50,000 in. lb. 5 ft. specimen	None	No
Ohio State University	16 ± senior	Yes	No	No	No	No	Olsen 50,000 in. lb.	Cold bend and Brinell hardness test	No
Penna. State College	16 senior	Yes	No	No	No	No	Olsen 60,000 in. lb., with "troptometer"	Cold bend, belt, chain	No
Penna., Univ. of	15 junior	Yes	Yes	No	Impact	Yes	Olsen 60,000 in. lb.	None	Strain-gauge
Washington, Univ. of	10 senior	Yes	No	No	Only as optional problems	Not for all men	None	None	No
Wisconsin, Univ. of	20 junior	To some extent	No	No	Impact only	Yes, some	Thurston and Riehle	Impact	No

able that if experiments follow the class-room discussions within a reasonable time that very little is to be gained by requiring students to read references just before entering the laboratory. On the other hand if some considerable interval elapses between the time when the student has the theory in the class-room and the practice in the laboratory, it is evident that if the student reads preliminary references just before entering the laboratory he will derive more benefit from his experimental work. The conclusion is at once reached that laboratory experiments should follow the underlying theoretical class-room work as quickly as possible. The sixth question asks if class-room work parallels or precedes the laboratory course and which is better? At least three fourths of the replies indicate a preference for conducting class and laboratory work together. It is probable, however, that this question was not sufficiently clear. It was intended to ascertain whether class and laboratory work are given during the same term, or whether the class-room work is given during one term and the laboratory work follows in a subsequent term. The answers indicate that class and laboratory work should be given in the same term.

In the matter of fees charged for laboratory work, there is again a wide diversity of practice. The reports indicate that at at least three institutions no charge is made. The maximum amount reported is $6.00 for a materials-laboratory course.

Materials Laboratory.

The replies to questions have been collected in Table II under nine heads as indicated by the numbers below.

1. The number of exercises averages about 15, with a minimum of 5 and a maximum of 34. It is evident that the attempt in most schools is to give one exercise per week for one half year.

The majority of institutions give a course in the junior year, the replies being as follows: Junior year, 11; sophomore year, 1; senior year, 3; junior or senior, 1; first and second years of three-year course, 1. Answers to this question have a bearing on the time in the student's course when he should be studying mechanics of materials and materials testing. If practice properly indicates the time it would seem that the junior year is the best.

2. Answers indicate that it is common practice to provide students with blank forms upon which to record their experimental results. Eleven answers are "yes," six "no," and two are "to some extent."

3. At very few institutions is shearing deflection considered in comparing the computed and observed center deflection of beams; two state that it is done "sometimes"; one answers "yes"; one answers "advance work only"; and fourteen answer "no."

4. Four institutions reporting the use of mirror extensometers agree that these instruments are satisfactory. The object of this question is to ascertain whether experimenters are attempting to secure greater accuracy in readings, especially under low loads.

5. Vibratory or impact tests are given to undergraduates at only five schools, of these three answering "yes" and the other two "impact only."

6. As might be expected. the majority do not favor vibratory or impact tests for undergraduates, eleven replying in the negative, three in the affirmative and the remainder giving such qualified answers as "yes, some," "of moderate value," "not for sophomores."

7. The use of torsion machines is reported by most institutions, the machines varying in capacity from about 10,000 to 230,000 inch-pounds.

8. Most replies answer "none" to the request for any new or unusual tests for undergraduates. Those mentioned as unusual are the impact tests; tests of riveted joints, of tile and sewer pipe; and Brinell hardness tests.

The following experiments are included in the various lists:

(*a*) Tension tests of steel, cast iron, wrought iron, steel and copper wire, timber, and brass with extensometer.
(*b*) Commercial tension tests of wrought iron and various grades of cast iron and steel.
(*c*) Autographic tension tests of steel.
(*d*) Tension tests of overstrained and annealed steel.
(*e*) Tension tests of rope.
(*f*) Compression tests of timber using a compressometer.
(*g*) Compression tests of timber, steel and wrought iron columns.
(*h*) Compression tests of short cylinders of wrought iron, cast iron and various grades of steel with and without use of compressometer.
(*i*) Cross-bending tests of large timber beams, of steel rails and of steel I-beams.
(*j*) Cross-bending tests of small beams of cast iron, wrought iron, steel, and timber.
(*k*) Shear tests of steel and wrought iron.
(*l*) Torsion tests of steel and wrought iron.
(*m*) Cold bending tests of steel.
(*n*) Impact tests of steel castings, timber and cast iron.
(*o*) Compression, cross-bending, and absorption tests of building and fire brick.
(*p*) Compression, cross-bending, absorption and rattler tests of paving brick.
(*q*) Shear and compression tests of timber parallel to and at right angles to the grain.
(*r*) Cross-bending tests of timber of varying moisture content.
(*s*) Transverse tests of timber or steel beams to verify elastic curves.
(*t*) Tests to determine effect of time element on cross-bending properties of timber.
(*u*) Tests of riveted joints.
(*v*) Tests of drain tile.
(*w*) Tests of building stone.
(*x*) Tests to determine the effect of cold twisting on steel.
(*y*) Repeated stress tests on ferrous metals.
(*y*) Brinell hardness tests.
(*z*-1) Study of testing machines.
(*z*-2) Calibration of testing machines.
(*z*-3) Calibration of extensometers.

TABLE III.

List of Experiments at the Various Institutions.

Materials Testing Laboratories.

Armour Institute of Technology.

Simple tension test. Tension test with extensometer. Torsion test. Compression tests of long and short columns. Transverse tests of long and short beams.

Carnegie Institute of Technology.

Compression of timber. Extensometer test of structural steel. Cross-bending of timber. Study of machines. Impact test of cast iron and steel castings. Commercial test of steel. Extensometer test of steel. Compression, shear, cold-bending and tension tests of steel and tension test of wrought iron. Tension test of over-strained and annealed steel. Torsion test of steel. Tension test of different grades of cast iron. Extensometer and compression test of cast iron. Cross-bending and torsion test of cast iron. Compression, cross-bending and absorption tests of building brick. Ditto, and rattler test of paving brick. Compression, shear, tension and cross-bending tests of timber. Cross-bending tests of timber of varying percentages of moisture content.

Cornell University.

Study of testing machines. Calibration of testing machines. Calibration of extensometers. Commercial and extensometer tests of wrought iron and steel in tension. Torsional tests of wrought iron and steel. Flexure tests of wrought iron and steel. Compression of woods along and across the grain. Shearing of woods along the grain; flexure of woods. Special studies in senior year includes tests of riveted joints, beam connections and effect of rate of loading upon elastic properties of steel.

Harvard University.

Tensile tests of wrought iron and steel. Compressive tests of wood and brick. Test of riveted joints. Bending tests of wood and cast iron.

College of Hawaii.

Handling calculating instruments as Thacher slide rule, Fuller slide rule, Brusvega machine and comptometer. Handling planimeter. Flash test of various oils. Viscosity test of various oils. Study of testing machines. Transverse test of wood (using 10,000-lb. machine). Compression of wood (short columns). Compression of wood (long columns). Tension of wood (using Olsen's micrometer extensometer). Torsion of wood. General test of bricks (compression, transverse, absorption, specific gravity, etc.). Tension cast iron, tension wrought iron, tension steel (using Olsen electric contact micrometer extensometer). Torsion of wrought iron, torsion of steel (using bar clinometer for measuring deflection). Tension of steel using bars which have been twisted at least three complete times in torsion machine, comparing results with those obtained in previous tension test, noting especially the effect on elastic limit. Tension of wrought iron using some type of autographic apparatus. Tension as above using another type. Study of steam engine indicator. Tension of wrought iron using steam engine indicator as an autographic recorder. Tests of fuse wire. Experiments with D.C. motor and Prony brake. Coal testing including use of Carpenter's calorimeter, determination of volatile matter, moisture, ash, etc. Junker's gas calorimeter testing calorific value of gas (illuminating oil gas). Junker's oil calorimeter testing calorific value of oil (fuel, oil, gasoline, etc.). Compression test,—cubes of local rock. Tension tests of rope and steel cable including practice in preparing specimen; putting on clevis. Tests for spike holding powers of various timbers used as ties, ohia, eucalyptus, redwood and N.W. Friction test of various oils, using Thurston's machine. Transverse test of cast iron bar; also wrought iron bar. Test of quality of steam using throttling and separating calorimeters. Transverse test of large size specimen of wood (10″ x 16″ x 16′ using 150,000-lb. machine). Transverse test of an I-beam. Test of wood in shear.

Iowa State College.

Calibration of testing machine. Tension and shearing tests of wood. Bending and compression tests of wood and effect of moisture. Bending tests of cast iron and wrought iron. Tension tests of steel with Marshall extensometer and wrought iron with Berry strain gage. Tension tests of steel and copper wire. Torsion tests—cold rolled steel shafting, mild steel or wrought iron. Tension test of steel—automatic diagram. Bearing and absorption tests of clay and cement sewer pipe or drain tile. Rattler and absorption test of paving block. Test of steel I-beam —verification of elastic curve.

State University of Iowa.

Study of the Riehle testing machine. Strain diagram of steel under tension. Strain diagrams of cast iron and wood in compression. Strain diagram of steel with an extensometer and effect of repeating the load. Test of cast iron and brick under cross-bending.

University of Kansas.

Study of the universal testing machine. Commercial tension test of iron and steel. Compression test of concrete cylinder, or the Brinell test for hardness. Tension test of wrought iron with extensometer. Tension test of steel with extensometer. Tension test of cast iron. Compression test of wrought and cast iron. Compression test of steel. Compression test of wood. Torsion test of wrought iron. Torsion test of steel. Transverse test of wrought and cast iron. Transverse test of wood. Rattler test of brick. Transverse, crushing and absorption test of brick.

Lehigh University.

Study of testing machines. Commercial test of steel and wrought iron. Shear and tension test of steel and wrought iron. Cold-bend tests on steel and wrought iron. Tension and shear tests of wood. Compression test of wood. Modulus of elasticity of steel in tension. Transverse tests of wooden beam. Transverse tests of a steel H-beam. Transverse test of cast iron. Torsion test of steel. Test of round- and fixed-ended wooden columns. Test of steel car spring for torsional stress and shear modulus of elasticity. Calibration of testing machine.

University of Maine.

Tension test of cast and wrought iron. Tension test of machinery and cold rolled steel. Compression test of short columns, cast and wrought iron. Compression test of machinery and cold rolled steel. Compression test of wood. Compression test of long columns—wood. Compression test of wrought iron. Compression test of brick and paving blocks. Compression test of concrete blocks. Transverse test of wooden beam. Transverse test of cast iron beam. Transverse test of steel I-beam. Torsion test of iron and steel. Direct shearing tests. Tests of hardness by Scleroscope.

McGill University.

Tension test of wrought iron and steel (Wicksteed machine). Compression tests and study of Riehle machine. Tests of various kinds of wire. Elasticity experiments (steel, wrought iron, copper and brass), small sized Wicksteed machine. Deflection of timber and metal beams. Deflection of a railway rail—modulus figure. Torsion of shafts. Coefficient of rigidity of a wire by torsional oscillations. Demonstrations on bricks, concrete, timber and reinforced beams.

University of Missouri.

Tension, transverse, torsion and cold-bending tests of steel, wrought iron and cast iron. Tension, compression, column and shearing of wood.

Ohio State University.

Tension.

Effect on elastic limit due to repeated loads in tension for wrought iron bar (8 hours). Ditto for soft steel bar (8 hours). Determination of unit stress, percents elongation and reduction of area, and coefficients of elasticity and resilience for wrought iron and steel bars in tension (4 hours). Commercial tests of wrought and steel bars, and boiler plate in tension (4 hours). The effect on tensile strength due to twisting for use in concrete steel reinforcement for wrought iron and steel bars (4 hours). Tension, compression and transverse tests on the same wrought iron, or steel bar (4 hours).

Compression.

Variation in compressive strength with variation in length of test piece, for wrought iron or steel bar (4 hours). Variation in compressive strength with variation in length of test piece, for white and yellow pine (4 hours). Determination of unit stress for different materials in compression (4 hours).

Transverse.

Verification of Hooke's law and determination of coefficient of elasticity for 6″ steel I-beam (2 hours). Effect on strength of beam due to change in shape of cross-section and length, for cast iron beams of one inch cross-section (4 hours). The effect on transverse strength of one inch square bar due to twisting bar as for concrete steel reinforcement (4 hours). Determination of maximum fiber stress and coefficient of elasticity for iron, steel, or wooden beams (4 hours).

Torsion.

Determination of shearing stress in outer fiber and coefficient of elasticity for cast iron, wrought iron, and soft steel bars in torsion (6 hours). The strength of a one inch square wrought iron bar (4 hours). The strength of a hollow iron, or steel shaft, as compared with that of a solid shaft.

Pennsylvania State College.

Flexural test on cast iron. Flexural test on steel. Flexural test on wooden beam. Tension test with micrometer. Tension test with autographic extensometer. Compression test on cast iron. Compression tests on wood. Torsion tests of steel, wrought iron and cast iron. Shearing test of steel. Shearing test of wrought iron. Shearing test of wood. Commercial test of steel and wrought iron. Cold bending test of steel and wrought iron. Test of wooden column. Tests of building brick and building stone. Belt and chain testing.

University of Pennsylvania.

Study of testing machines. Commercial tension tests on wrought iron and steel. Shear and tension tests on wrought iron and steel. Modulus of elasticity of iron and steel with extensometers. Torsion tests on iron and steel. Wooden columns. Transverse test on cast iron. Transverse test on steel I-beam. Transverse test on wood. Rattler, transverse and absorption tests of paving brick. Cold bend test on iron and steel. Shearing strength of wood. Tension tests on cast iron.

University of Washington.

Test of large timber beam (8″ x 16″ x 15′). Test of small beams. End compression test of wood. Side compression test of wood. Shearing test of wood. Commercial test of steel in tension. Extensometer test of steel in tension. Transverse test of cast iron. Compression test of concrete. Impact test of timber.

University of Wisconsin.

Compression test of wood with compressometer. Tension test of mild steel with extensometer. Cross-bending test of wooden beam, with deflectometer. Impact test of cast iron. Test of structural steel column, optional. Torsion test of steel. Study of lever and hydraulic testing machines. Tensile test of steels varying in carbon content. Extensometer tension test of steel and compression test of steel. Various tests of wrought iron and steel; commercial tensile, shear and cold bending. Effect of overstrain and subsequent annealing of steel. Tensile test of white, gray and malleable cast iron. Extensometer tension test and compression test of cast iron. Cross-bending, impact and torsion test of cast iron. Cross-bending and shear tests of different woods. Compression and impact tests of woods. Cross-bending tests of wood differing in moisture content. Effect of time element on cross-bending strength of timber. Tests of paving brick. Tests of building brick. Repeated stress test on ferrous metals, optional.

Hydraulic Laboratory.

Fourteen reports received give more or less complete data. The work is commonly scheduled in the junior year from three to sixteen exercises per term.

In five institutions blank forms are provided for experiments and seven state that they are not used.

Nothing novel relating to weirs is suggested except a float gage in use at Cornell and a special form of piezometer open-

TABLE IV.

Giving Summary of Answers to List of Questions Regarding Hydraulic Laboratories.

Name of Institution.	1 Number of Exercises per Year.	2 Are Blank Forms Provided?	3 New Forms of Weirs or Method of Measuring Head.	4 How is Uniform Pressure Secured?	5 Are These Methods Satisfactory?	6 Suggestions for Securing Uniform Pressure.	7 Are Mercury Columns Used?	8 Does Mercury Cause Corrosion in the Glass Tubes?	9 How is This Trouble Overcome?	10 How is Blowing Out of Mercury from Pressure Gages Prevented?
Armour Inst. Tech.	9 junior	Yes	None	Steam turbine governor	Yes	None	Yes	No	....	"Watch them"
Carnegie Inst. Tech.	15 junior	No	None	Pressure tank and air cushion	......	None	Yes	....	....	....
Cornell University	None	......	Float gage	....	......	....	Yes	Rust from iron parts	Wash and strain	Have little trouble
Harvard University.	16	Not in general	None	Overflows mainly	Not always	Larger overflows and close watching	Yes Freeman type	Some	....	"Do not always prevent it"
College of Hawaii	....	......	....	....	......	....	....	....	....	....
Illinois, Univ. of	16 junior	No	None	Stand pipe	Yes	....	For some work	To some extent	....	Stop-cocks
Iowa, State Univ. of	6 junior	No	None	Air cushion	Yes	None	No	....	....	....
Iowa State College	8 or 9 senior	No	None	Stand pipe 40′ high, 30″ diam.	Yes	....	No	....	....	....
Kansas, Univ. of	....	......	....	....	......	....	....	....	....	....
Lehigh University	14 junior	Yes	None	Stand pipe with overflow weirs	Yes	....	Yes	Yes	....	Tubes bent at top over vessel

TABLE IV—*Continued.*

	1	2	3	4	5	6	7	8	9	10
Name of Institution.	Number of Exercises per Year.	Are Blank Forms Provided?	New Forms of Weirs or Method of Measuring Head.	How is Uniform Pressure Secured?	Are These Methods Satisfactory?	Suggestions for Securing Uniform Pressure.	Are Mercury Columns Used?	Does Mercury Cause Corrosion in the Glass Tubes?	How is This Trouble Overcome?	How is Blowing Out of Mercury from Pressure Gages Prevented?
Maine, Univ. of	3 junior*	......	....	....	....	....	.....	....	....	....
McGill University..	12 senior	No	None	Draw from mains. Valves	Yes, approx.	None	Yes	Water sediment only	....	Not prevented
Michigan, Univ. of .	....	Hydraulic laboratory not yet equipped				....	.....	....	....	....
Missouri, Univ. of..	....	Hydraulic laboratory being constructed				....	.....	....	....	....
Ohio State University............	8–10 senior	Yes	No	Supply valve and waste valves	Yes	None	Yes	....	....	....
Penna. State College	16 junior	Yes	None	Stand pipe and valves	Fairly satisfactory	None	Yes	No	....	Watch
Penna., Univ. of ...	15 junior	Yes	No	Stand pipe with overflows	Yes	Electric control	Yes	Yes	....	Have little trouble
Washington, Univ. of	16 junior	No	None	Large free water-surface and long "header"	Yes	....	Yes	The usual trouble with corrosion	Filtering mercury and clean tube	Long tube and small stop-cocks
Wisconsin, Univ. of.	5 junior	No	Special form of piezometer opening for submerged weir	Elevated tank and float valve	Yes	Pressure tank and overflow to reservoir	Temporarily	No	....	Long open "leg" and bend over vessel

ing for submerged weirs at the University of Wisconsin. The methods employed of securing uniformity of pressure vary, eight different ways being recorded. Despite this variation in practice, only three replies indicate any dissatisfaction; one writer suggesting the use of larger overflows as a remedy for variations in pressure but no novel methods of securing uniform pressure are presented. Eleven laboratories have mercury gages as a part of their regular equipment and two do not use them. It would appear that little trouble is experienced in the use of such gages because of corrosion in the glass tubes. Washing, straining or filtering the mercury are mentioned as a means adopted for overcoming the corrosion of the mercury with the consequent discoloration of the glass. Blowing out of mercury from the open leg of mercury gages seems to cause some difficulty, but the use of a long tube bent at the top over an open vessel prevents the loss of mercury.

The lists of experiments vary widely and include principally the following, the figures at the right indicating the number of cases where the particular experiment was mentioned:

1. Experiments upon weirs	11
2. Experiments upon orifices	11
3. Tests of Venturi meter	9
4. Calibration of water meters	8
5. Impulse wheels	8
6. Test of pumps, centrifugal and otherwise	7
7. Experiments upon nozzles	6
8. Loss of head in pipes	6
9. Experiments and Pitot tubes	5
10. Study of path and cross-section of jets	5
11. River gaging	5
12. Calibration of pressure gages	4
13. Turbines	3
14. Test of hydraulic ram	3
15. Measurement of slope of water surface	2
16. Calibration of differential gages	1
17. Calibration of current meters	1
18. Determination of zero of gages	1
19. Weighing water	1
20. Loss of head in bends	1

21. Loss of head in sudden contractions	1
22. Pressure due to jets	1
23. Test of pressure engine	1
24. Measurement by rod floats	1
25. Determination of discharge coefficient of dam	1

TABLE V.

List of Experiments at the Various Institutions.

Hydraulic Laboratories.

Armour Institute of Technology.

Calibration of weir notch. Calibration of a water meter. Calibration of a Venturi meter. Test of an hydraulic ram. Test of a centrifugal pump. Calibration of a nozzle. Test of an impulse water wheel. Loss of head in pipes. Use of Pitot tubes for measuring flow of water.

Harvard University.

Gage calibrations, weirs, orifices, nozzles, Venturi meter, weighing water, pumps and Pelton wheel. For civil engineers, in addition: At Lowell, Mass., rod floats, current meters, large nozzles, friction head in pipes in service, slopes in canals, pitometers, and Pitot tubes, turbines as water meters, complete turbine tests.

Iowa State College.

Calibration of triangular and rectangular weirs. Coefficient of discharge of standard orifice. Calibration of Venturi meter. Calibration of water meters. Friction losses in straight pipes. Calibration of pressure gage. Efficiency test of hydraulic ram. Efficiency test of centrifugal pump. Efficiency test of water meter. Measurement of river discharge with current meters.

State University of Iowa.

Orifices: Zero of gage, coefficient of discharge, measurement of section and path of jet. Standard contracted weir, determination of coefficient. Calibration of Venturi meter. Current meters and dam coefficients. Gaging Iowa river, vertical and horizontal velocity curves, coefficient of discharge of University Power Plant dam.

Lehigh University.

Study of laboratory. Calibration of measuring tanks. Depth of flotation and loss of weight by immersion. Determination of the path of a jet. Test of displacement water meter. Test of Venturi meter. Determination of coefficient of discharge for standard vertical orifice (round). Determination of coefficient of discharge for standard vertical orifice (square). Determination of coefficient of discharge for standard weir (V-notch). Determination of coefficient of discharge for standard weir (rectangular). Determination of coefficient of friction in pipes. Study of hydraulic gradient. Efficiency test of a hydraulic turbine. Efficiency test of a Pelton wheel. Efficiency test of hydraulic ram. River gagings.

University of Maine.

Coefficients of weirs. Flow of water through nozzles and orifices. Calibration of water meters.

McGill University.

Discharge coefficient for an orifice. Venturi meter. Frictional resistance in pipes. Hydraulic ram. Flow over notches of various forms. Pressure exerted by a jet impinging on surfaces of various forms. Hydraulic motors: Pelton and Girard wheels and Brotherhood engine.

Ohio State University.

Determination of efficiency and ratio of water pumped to water supplied for Humphrey's hydraulic ram (8 hours). Comparative tests on 1 inch frictionless, short pipe, and rounded edge orifices (4 hours). Variation of coefficient of discharge with variation in head for frictionless orifice (4 hours). Determination of contour of jet issuing from a frictionless orifice (4 hours). Determination of diameter and velocity of jet issuing from a frictionless orifice (4 hours). Variation of coefficient of discharge with variation in diameter of orifice, constant head and no velocity of approach (8 hours). Variation of coefficient of discharge with variation of diameter of orifice, constant head and velocity of approach (8 hours). Variation of coefficient of discharge with variation of head for conical nozzle (4 hours). Determination of ratio of mean velocity to center velocity for flow of water, or air, in a pipe line (8 hours). Calibration of cistern, or bay, in the hydraulic laboratory, M.E. Dept., The Ohio State University (4 hours). Calibration of 1500 gallon closed measuring tank (4 hours). Variation of quantity discharged and of weir constant with variation in head for 60° triangular weir (8 hours). Ditto for rectangular weir (8 hours). Variation of efficiency with variation of speed for impulse water wheel (8 hours). Variation of efficiency due to variation in load and speed for 10″ Leffel standard turbine, constant head (8 hours). Determination of quantity discharged and coefficient of discharge for a 3-inch Venturi meter (8 hours). Measurement of the flow of air by means of a Pitot tube and standard orifice (8 hours). Determination of the variation of velocity across the diameter of an air pipe line (8 hours). Determination of efficiencies and duty of a 20-inch Worthington single stage centrifugal pump dirert connected to a 200 H.P. vertical cross compound Buckeye engine (20 hours). Duty test of a direct acting steam pump (8 hours). Determination of maximum capacity for a 2″ pulsometer, under varying steam pressures (8 hours).

Pennsylvania State College.

Experiments on weirs, orifices, nozzles, and Venturi meters. Calibration of pressure gages and water meters.

University of Pennsylvania.

Loss of weight due to immersion; depth of flotation. Coefficients of standard orifice and short tube. Calibration of mercury gage. Test of pressure gage. Discharge for orifice under decreasing heads. Venturi meter. Water meter. Path of jet. Weirs. Friction in pipes. Nozzles and fire hose. Chezy's and Kutter's formulæ. Pitot tube. Turbine. Impulse wheels. Efficiency test of electrical motor. Test of centrifugal pump.

University of Washington.

Establishing a current meter gage station in canal or river. Determination of friction loss in pipes. Study of losses in bends, etc. Computing flow in canal, or river, by slope measurement, checking with current meter work. Determination of efficiency of nozzles. Loss by sudden contraction of nozzles. Complete test of impulse water wheel for power, efficiency and speed factor.

University of Wisconsin.

For course in theoretic hydraulics.

Calibration of differential fluid gage. Calibration of circular orifice. Calibration of rectangular overfall weir. Calibration of Pitot tube. Calibration of Venturi meter.

Cement Laboratory.

Replies were received from eighteen colleges and schools, a number of these replies being somewhat incomplete.

1. Average number of exercises per year given in fifteen laboratories is about ten, the minimum being five and the maximum twenty. This variation is due in part to a difference in combining certain tests; for example, the commercial

TABLE VI.

GIVING SUMMARY OF ANSWERS TO QUESTIONS REGARDING CEMENT LABORATORIES.

	1	2	3	4	5	6	7	8	9	10	11
Name of Institution.	Number of Exercises per Year.	Is Preliminary Reading Required? Are Preliminary Instruction Sheets Provided?	Do You Test Good Cement Only? How Illustrate Defects in Cement?	What Specific Gravity Glass is Used?	Suggestions Regarding Sp. Gr. Test by Students.	How do You Avoid Troubles with the Le Chatelier Apparatus?	Have You Used New Ball and Socket Compression Block for Small Cubes? Give Experience.	Have You Any New Devices Which Have Proved Satisfactory?	Do Your Students Ever Try Making Portland Cement?	Do the Students Study Sand and Stone? What Is Done?	What Readings Are Taken in Testing Concrete Beams?
Armour. Inst. Tech.	9	Yes. Yes	Yes. Explain	Le Chatelier	None	Have no trouble	No	No	No	Yes. Time set and strength. Sieve analysis	Loads and deflections at center
Carnegie Inst. Tech.	7 junior	Yes. Yes	Test both kinds	Le Chatelier	None	Have no trouble	No	No	No	Yes	Loads, deflections, and deformeters
Cornell University	5 soph.	No. —	Yes. Explain	Le Chatelier	None	Have very little trouble	No	No	No	Yes	Loads, deflections, and deformeters
Harvard University	5 reg'd*	Yes. Yes	Both kinds	Le Chatelier	None	Have no trouble	No	....	No	Yes	....
College of Hawaii	......	Yes. —	Yes. Explain	Le Chatelier Chandlot	None	....	No	No	......	Yes	Loads and deflections at center
Illinois, Univ. of	12 senior	Yes, in manual	Yes. —	None	None	....	No	....	No	A little	None given
Iowa, State Univ. of	......	Course consists of one demonstration lecture							......	....	....
Iowa State College	17 junior	No. Yes	Test both kinds	Le Chatelier	None	Eternal vigilance	No	....	No	Yes	Not often made by students

TABLE VI—*Continued.*

	1	2	3	4	5	6	7	8	9	10	11
Name of Institution.	Number of Exercises per Year.	Is Preliminary Reading Required? Are Preliminary Instruction Sheets Provided?	Do You Test Good Cement Only? How Illustrate Defects in Cement?	What Specific Gravity Glass is Used?	Suggestions Regarding Sp. Gr. Test by Students.	How do You Avoid Troubles with the Le Chatelier Apparatus?	Have You Used New Ball and Socket Compression Block for Small Cubes? Give Experience.	Have You Any New Devices Which Have Proved Satisfactory?	Do Your Students Ever Try Making Portland Cement?	Do the Students Study Sand and Stone? What is Done?	What Readings Are Taken in Testing Concrete Beams?
Kansas, Univ. of	15 senior	Yes. Yes	Yes. Explain	Le Chatelier	None	Asbestos cushion in glass cylinder	No	No	No	Sand only	None
Lehigh Univ.	15 senior	Yes. Yes	Yes. Explain	Le Chatelier	None	Very little trouble	No	No	No	Voids and mechanical analysis	Deflections and deformations
Maine, Univ. of	15 senior	No. Yes	Yes. Explain	Le Chatelier	None	Due care	No	No	No	Yes	....
McGill University	5 junior	No. No	No. Adulterate	Schuman volumeter	None	....	No	No	No	No	Deflections and deformations
Michigan, Univ. of	5	Yes. —	No. —	Burrett	......	See Col. 4	No	......	No	Yes, voids and sp. gr.	Center load and deflections
Missouri, Univ. of	12 1st and 2d yrs. of 3-yr. course	No. Yes	Test both kinds	Le Chatelier	None	Students make good all breakage	No	No	No	Yes	Deflection load at cracking, breaking load, and fiber changes

TABLE VI—*Continued.*

	1	2	3	4	5	6	7	8	9	10	11
Name of Institution.	Number of Exercises per Year.	Is Preliminary Reading Required? Are Preliminary Instruction Sheets Provided?	Do You Test Good Cement Only? How Illustrate Defects in Cement?	What Specific Gravity Glass is Used?	Suggestions Regarding Sp. Gr. Test by Students?	How do You Avoid Troubles with the Le Chatelier Apparatus?	Have You Used New Ball and Socket Compression Block for Small Cubes? Give Experience.	Have You Any New Devices Which Have Proved Satisfactory?	Do Your Students Ever Try Making Portland Cement?	Do the Students Study Sand and Stone? What is Done?	What Readings Are Taken in Testing Concrete Beams?
Ohio State Univ.	20	Yes. —	Yes. —	Le Chatelier	None	....	Yes. Works very well	Cone test for consistency	......	....	Concrete and steel deformations. Deflections
Penna. State College	8 senior	No. Yes	Yes. Nothing	Le Chatelier	None	Wood block in vessel for cushion	No	....	No	No	None
Penna., Univ. of	14 senior	....	Yes. Adulterate	Le Chatelier	None	Little trouble	No	No	No	No	Concrete and steel deformations. Deflections
Washington, Univ. of	6 senior	Yes. Johnson, Taylor, and periodicals	Yes. —	Le Chatelier	None	Students pay breakage. Thorough cleaning insisted upon	No	No	No	Yes. Voids, proportions, and varying mixes	No beams made
Wisconsin, Univ. of	8 junior	No. Yes	Test both kinds	Test not rqd.	Would abolish test for students	See Col. 4	No	Study of sands	No	Yes	Deflections and deformeter

tests of cement which include tests for fineness, specific gravity, time of setting, tensile strength and soundness is considered as one exercise by some and as several by others.

Cement laboratory work is offered by seven schools in the senior year, four in the junior year, one in the sophomore and by one in the first and second years of a three years' course.

2. Laboratory instruction sheets are generally provided, although in a few cases these consist only of pamphlets on cement testing issued by the American Society of Testing Materials and American Society of Civil Engineers.

Most laboratories test only good cement, and the action of poor cements is explained to students in several schools. In one laboratory the cement is adulterated with plaster of Paris, or lime; in another, arrangements are made with the cement manufacturer to furnish an overlimed cement in order to produce unsoundness. Five institutions test both good and poor cements, three report that defective samples are shown. It would, therefore, appear that in about one half of the schools the students do not see the action of cements which fail to pass requirements.

4. The LeChatelier specific gravity flask is very generally used; fourteen institutions reporting its use, one the Burrett, one the Schuman Volumeter, while in at least two the test is not made. One of the latter reports states "found that unless we gave an unreasonable amount of time to it that students could not get reports of any value." The second report states "do not require students to make specific gravity tests. Am a strong advocate of the abolishment of this test, at least in student work."

5. Quite a number of reports agree that it is difficult to get good results in the specific gravity tests; others indicate that although it is difficult the experiment is a good one because it teaches the student to be careful in manipulation.

6. As to trouble with the LeChatelier apparatus regarding breakage or cleaning, several do not answer; some state they have very little trouble and others indicate considerable breakage.

7. The new ball and socket compression block for testing small cubes has been used in only one laboratory and is reported to "work very well." Spherical bearings, however, are usually employed in these tests.

8. The only new devices mentioned are the yield point cylinder, and silt apparatus used in studying the properties of sands.

9. In none of the laboratories is Portland cement made by students, it being regarded by some institutions as a work for the chemical department.

10. While there is considerable variation in experiments on sand and stone the following list may be taken as representative:

(*a*) Determination of unit weights.
(*b*) Determination of percentage of voids.
(*c*) Determination of specific gravity.
(*d*) Mechanical analysis.

The more common tests are:

(*e*) Effect of variation in size of sand grains on tensile strength of mortar.
(*f*) Density of Portland cement mortar.
(*g*) Percentage of clay in sand.
(*h*) Effect of moisture on volume of sand.
(*i*) Percentage of loam in sand.

11. Experiments on concrete are not as common in the required courses as might be expected, eleven of the eighteen laboratories reporting experimental work on concrete beams. Several report compression tests of concrete. In two cases concrete tests are elective or may be taken as thesis work. In concrete beam tests, loads, deflections and fiber deformations are generally read.

TABLE VII.

List of Experiments at the Various Institutions.

Cement Laboratories.

Armour Institute of Technology.

Fineness, plasticity and time of setting—cement. Specific gravity, soundness, effect of temperature on settling—cement. Moulding of briquettes and cubes—re-tempering. Comparative strength of different mortars. Sieve analysis of sand and stone. Voids in sand and stone; concrete mixing. Concrete, with different sizes of stone; lime mortar. Reinforced beams, moulding. Time—strength tests.

Carnegie Institute of Technology.

Tension and compression tests of mortars and neat cement. Commercial tests of Portland cement. Study of concrete materials and compression tests of concrete of varying proportions. Reinforced concrete beam test. Effect of various grades of sand on tensile strength of mortar. Effect of fineness of cement on tensile strength of mortar. Commercial test of natural cement. Mechanical analysis of sand and stone.

Cornell University.

Specific gravity and fineness of cement. Normal consistency and time of setting of cement. Soundness and tensile strength of cement. Compressive strength of cement, and specific gravity of sand, gravel, and stone. Mechanical analysis of aggregates and voids in aggregates.

Harvard University.

Cement: sand; making and breaking briquettes.

College of Hawaii.

Normal consistency and time of set of cement. Devices for measuring specific gravity of cement. Fineness of cement and completion of specific gravity tests if more time required. Neat briquettes, making sufficient to test at required time intervals. 1 to 3 briquettes using standard sand. Concrete cubes for compression test. Modulus of elasticity of concrete. Neat briquettes molded under pressure using Olsen's machine. Investigation effect of adding waterproofing compounds to mortar, (*a*) as a means of waterproofing; (*b*) increase or decrease in strength of mortar. 1 to 3 briquettes using local sand. 1 to 3 briquettes using another local sand. Examination of sand used, fineness, specific gravity, voids, uniformity coefficient, effective size. Voids in crushed rock. Reinforced concrete beam molding; tested later. Bars of neat cement 1″ x 13″ tested transversely. Complete test and report on sample of cement.

University of Illinois.

Plasticity of Portland cement. Plasticity of Natural cement. Soundness, acid test. Sand tests. Tensile strength of neat cement at various ages. Fineness of Portland cement. Weight of cement. Tensile strength of mortar. Specific gravity, voids and weight of sand. Density of Portland cement mortar. Compressive strength of concrete.

Iowa State College.

Normal consistency and time of setting of cement. Specific gravity of cement. Soundness test of cement. Fineness test of cement. Tensile strength of cement (standard). Tensile strength of cement (varying proportions). Variation in tensile strength with amount of water. Weight of cement. Compressive strength of mortar. Compressive strength of concrete. Mechanical analysis of sand. Weight of sand.

State University of Iowa.

One demonstration lecture on cement testing.

University of Kansas.

Normal consistency. Activity. Soundness. Tensile strength—neat briquettes. Tensile strength 1–3 briquettes. Fineness of cement. Specific gravity of cement. Effect of rate of loading on strength of briquettes. Comparison of methods of molding briquettes. Solidity of cement mortar. Effect of varying percents of water on the strength of briquettes. Crushing strength of mortar. Effect of varying proportions of sand on the strength of cement mortar. Specific gravity of sand. Effect of moisture upon the volume of sand. Percentage of voids in sand. Sand analysis. Effect of hydrated lime on tensile strength of mortar. Percent of loam in sand.

Lehigh University.

Specific gravity of cement. Fineness test of cement. Normal consistency. Constancy of volume—normal test. Mechanical analysis of sands. Mixing and molding cubes and briquettes (neat and 1–3 mortar). 7-day tests of briquettes and cubes. 28-day test of briquettes and cubes. Determination of voids in aggregates. Mixing and molding of 13-ft. reinforced concrete beam. Test of reinforced concrete beam. Mixing and molding five standard compression cylinders. Test of cylinders. Mixing and molding of 5-ft. plain concrete column. Test of column.

University of Maine.

Normal consistency test. Pat test for soundness. Test for fineness. 24-hour Portland cement, neat. 7-day Portland cement, neat and standard sand. 7-day Natural cement, neat and standard sand. 28-day Portland cement, neat and standard sand. 28-day Natural cement, neat and standard sand. Plotting curves of tensile strength. Specific gravity determination. Time of setting. Boiling test for soundness. Steam test for soundness. Comparative test at 7 days. Comparative test at 28 days. Uniformity test. Tensile strength—consistency test at 7 days. Tensile strength—consistency test at 28 days. Test of sand and aggregates. Specifications for cement. Chemical test for excess of lime and adulterants. 7-day Portland cement and commercial sand. 28-day Portland cement and commercial sand. Crushing test of 28-day Portland cement, neat, standard sand, commercial sand.

McGill University.

Normal consistency. Specific gravity. Time of setting of cement. Fineness of cement. Tensile strength of cement. Soundness of cement.

University of Michigan.

Normal consistency. Specific gravity. Time of setting of cement. Fineness of cement. Tensile strength of cement. Soundness of cement. Specific gravity and voids—sand. Compression tests of concrete. Cross-bending tests of reinforced concrete beams.

University of Missouri.

Specific gravity of cement. Fineness of cement. Time of setting of cement. Soundness of cement. Consistency of mortar. Tensile, compressive and transverse strengths of cement and cement mortar. Voids in cement, sand and broken stone. Specific gravity and fineness of sand and stone. Crushing tests of concrete. Beam and bond tests of reinforced concrete.

Ohio State University.

Consistency. Activity. Soundness. Tensile strength 1–3 Canada sand, 7 and 28 days. Tensile strength 1–3 Standard Ottawa sand. 7 and 28 days. Tensile strength—neat cement 1–7 and 28 days. Fineness of cement. Specific gravity of cement. Voids and specific gravity of sand. Dirt and loam in sand. Mechanical analysis of sand (sifting). Weights of sand. Weights of stone, gravel and concrete. Voids and specific gravity of stone. Mechanical analysis of stone (screening). Consistency of sand mortars, cone test for comparative tests. Tensile strength 72 hours and 7 days for comparative tests.

Pennsylvania State College.

Fineness of cement. Specific gravity of cement. Normal consistency of cement. Tensile strength of cement. Compressive strength of cement. Time of setting of cement. Constancy of volume of cement.

University of Pennsylvania.

Fineness. Specific gravity. Normal consistency. Time of setting. Constancy of volume. Tensile strength. Compressive strength. Modulus of rupture. Percent of loan and mechanical analysis of sand. Void determinations. Strength of and modulus of elasticity of concrete. Reinforced concrete beam.

University of Washington.

Specific gravity of cement. Normal consistency of cement and neat briquettes. Mortar briquettes (standard sand). Accelerated (soundness) tests, fineness and time of set. Cement mortars (various sands, cements and mixtures). Determination of voids in sand and stone. Compression tests of concrete.

ROAD MATERIALS LABORATORY.

The data submitted under this head are so very few that no generalization regarding equipment, experiments and conduct of road materials laboratories is justified. Of the seven replies, five state the tests to be of value to students and one uses the phrase "not much value." The work is taken up as a senior subject in four schools, elective in one and not regularly required in two. Five institutions introduce the study of bituminous materials to a slight degree and in one case the work is done under the direction of the department of chemistry.

The list of experiments submitted include specific gravity, absorption, abrasion, hardness, toughness, crushing and cementation tests of stone, tests on paving brick and a study of bituminous materials as outlined in Bulletin No. 38, Department of Public Roads. Iowa State College reports the following experiments on road materials:

Cementing value of limestone.
Cementing value of trap.
Abrasion of gravel.

Abrasion of limestone.
Abrasion of trap.
Hardness of limestone.
Hardness of trap.
Toughness of limestone.
Toughness of trap.
Absorption of limestone and trap.
Specific gravity of limestone and granite.
Sieve analysis of sheet asphalt mixtures.
Sieve analysis of bitumen concrete mixtures.
Proportioning mineral aggregate for sheet asphalt mixtures.

In addition Iowa State College gives the following work in the Bituminous Materials Laboratory:

Penetration test on asphalts.
Flash and burning points on asphalts.
Flow point and melting point.
Ductility of asphalts.
Consistency of tars by the float test.
Free carbon in tars.
Total bitumen determination.
Asphatene determination.
Carbene determination.
Fixed carbon determination.
Distillation of tars.
Loss on evaporation.
Distillation of creosote oils.
Extraction of creosote oils from paving blocks.
Complete analysis of asphalt cement.
Complete analysis of semi-asphaltic fluxes.
Determination of asphalt cement in paving mixtures.
Preparation of an asphalt cement from a refined natural asphalt and flux.
Determination of viscosity of liquid asphaltic oils, using the Engler viscosimeter.
Complete analysis of a natural asphalt or a manufactured asphalt.

TABLE VIII.

GIVING SUMMARY OF ANSWERS TO QUESTIONS REGARDING ROAD MATERIALS LABORATORIES.

Name of Institution.	1 Number of Exercises Per Year.	2 List of Experiments.	3 Do You Consider These Tests of Much Value to the Student?	4 Do You Test Bituminous Materials?	5 Can You Suggest Improvements in Testing Machines or Any New Tests?
Armour Inst. Tech. ...	None regularly	...	Yes	...	...
Carnegie Inst. Tech. ..	...	...	...	...	...
Cornell University....	None regularly	...	...	...	...
Harvard University...	...	Rattler, Deval, Cementation	Considerable	No	...
College of Hawaii.....	...	...	...	...	...
Illinois, Univ. of......	...	...	...	...	...
Iowa, State Univ. of ..	...	...	...	...	...
Iowa State College....	1st term— Stone, etc., 14 2d term— Bituminous, 20	See Table IX	Yes	Yes	...
Kansas, Univ. of......	...	...	...	...	...
Lehigh University.....	...	...	...	...	...
Maine, Univ. of	15 senior	All tests of Bureau Pub. Roads, Wash.	Yes	Yes	...
McGill University.....	...	...	...	...	...
Michigan, Univ. of....	17 senior	See Table IX	Yes	Yes. Bulletin 38, Public Roads Dept.	No
Missouri, Univ. of....	17 elective	See Table IX	Yes	Yes. See Col. 2	...
Ohio State University .	...	...	...	...	...
Penna. State College ..	16 junior and 16 senior	See Table IX	Yes	Yes. See Col. 2	No
Penna., Univ. of......	...	...	...	...	...
Washington, Univ. of .	16 senior	See Table IX	Not much value	No. Given in chem. dept.	Study of existing streets and pavements and design of same
Wisconsin, Univ. of...	...	...	...	...	...

TABLE IX.

List of Experiments at the Various Institutions.

Road Materials Laboratories.

University of Michigan.

Specific gravity of road stone. Abrasion of road stone. Hardness of road stone. Toughness of road stone. Rattler test of paving brick. Specific gravity test of paving brick. Hardness test of paving brick. Toughness test of paving brick. Absorption test of paving brick. Test of bitumens as given in Bulletin No. 38, Office of Public Roads.

University of Missouri.

Specific gravity, absorption, crushing, abrasion, bonding and impact tests of stone. Specific gravity, solubility in carbon disulphide and naphtha, free carbon, fixed carbon, distillation, viscosity, float penetration, evaporation, melting point and paraffine tests of bitumen. Tests on paving brick.

Pennsylvania State College.

Junior Year.

For bitumens specific gravity, viscosity, consistency, melting point, flash and burning points, volatilization total bitumen, bitumen soluble in 88 per cent. naphtha, bitumen soluble in carbon disulphide, distillation of oils and penetration tests of bitumens. Binding value of bitumens; tensile strength of bitumens mixed with sand, stone, and sand and stone.

Senior Year.

Sieve analysis of sand and crushed stone. Toughness, hardness, cementation and abrasion tests of stone. Tests of paving brick.

University of Washington.

Absorption, hardness, toughness, cementation and abrasion of two kinds of rock.

Time Spent in Materials Testing Laboratory.

To ascertain the amount of time spent by students in experimental work in the materials testing laboratory and also the amount spent later in writing up reports, your committee has secured from one institution for the half year ending

February, 1914, reports from all civil engineering students taking materials testing laboratory work in the first half of their junior year. Each student had one laboratory exercise per week scheduled as a three-hour exercise. The amount of time spent within and without the laboratory was recorded each week by the student himself.

The fourteen experiments included in this summary are as follows: (1) Study of testing machines. (2) Commercial test of steel and wrought iron. (3) Shear and tension test of steel and wrought iron. (4) Cold-bend tests on steel and wrought iron. (5) Tension and shear tests of wood. (6) Compression test of wood. (7) Modulus of elasticity of steel in tension. (8) Transverse tests of wooden beam. (9) Transverse tests of a steel H-beam. (10) Transverse test of cast iron. (11) Torsion test of steel. (12) Test of round- and fixed-ended wooden columns. (13) Test of steel car spring for torsional stress and shear modulus of elasticity. (14) Calibration of testing machine.

There were fifteen laboratory periods of three hours each, but as each of two of the longest experiments was allowed two periods, each student really spent 13 exercises in the laboratory.

Table X, a summary of this information, shows that the average time spent in the laboratory by 36 men is 1.9 hours per exercise and the average time spent in writing reports out of the laboratory is 4.48 hours per exercise. Per scheduled exercise the student spent 6.38 hours whereas only 3 clock-hours were allowed him. Inasmuch as the laboratory counts for only one credit hour, *i. e.*, one term-hour, is it not fair to ask whether more credit should be given for the work done or whether the work is so valuable as to be assigned so much of the student's time? The answer to this question will depend largely upon the care with which a student does his work. If his work in the laboratory is of a hurried character and of a low grade, and if he simply breaks things without seeing the connection between the breaking and the theory, and furthermore, if he is allowed to hand in carelessly written reports, it

TABLE X.

Hours Spent by Individual Students in Laboratory Exercises and Afterwards in Writing Reports.

Student's Name.	Number of Experiment.																												Total.		Average.	
	1		2		3		4		5		6		7		8		9*		10		11		12*		13		14					
	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.
A	2½	4	3½	3	2½	3½	½	2½	1½	2½	1¾	6½	2¼	5½	1¼	5½	2	14	1	5½	1¼	4½	3	12	....	....	1	3½	24	72½	1.85	5.58
B	2½	4	3½	3	2	3¼	½	2½	1½	3	1¾	6	2½	5½	1¼	5½	2	14	1	4	1¼	4½	3	12	....	....	1	3½	23¾	70¾	1.83	5.45
C	2½	4	3½	3	2	4	½	2½	1½	4¼	1¼	4	2¼	5½	1¼	4¾	2	15	1	4	1¼	4	3	9	....	....	1	2	23	66	1.77	5.08
D	2½	4	3½	2½	2	3½	½	2	1½	2½	1¾	5½	2¼	5	1¼	5½	2	14	1	4	1¼	4	3	11	....	....	1	3½	23½	67	1.81	5.15
E	2½	2½	1½	2½	2	3¾	1½	2½	2	2¾	1	6	2	6	1	....	2	20	1	5	1	4½	3½	13	....	....	1	4	22	74½	1.83	5.73
F	2½	3	2	4	2	3¼	1½	3	1½	3½	1	4½	2	5½	1	4½	2	15	1	5	1	4	3½	12	....	....	1	3½	22	71	1.69	5.45
G	2½	2½	2	3½	2	2¾	1½	2	1½	3½	1	4	2	3½	1	4	2	11	1	4	1	4	3½	6	....	....	1¼	3	22½	56¾	1.73	4.36
H	2½	3	2	3¼	2	4½	1½	2	1½	2¾	1	4½	2	5	1	4½	2	14	1	4¾	1	3¾	3½	11	....	....	1	2	22	65	1.69	5.00
I	2½	1½	2	2½	3½	2	½	1	2	2	1¾	2¾	2	4½	2	5	3	12	1½	5	....	....	3½	8	1½	3	1½	1¾	27½	51	2.12	3.92
J	2½	2½	2	3¼	3½	2½	½	1¾	1½	1¾	1½	4	2½	4	2	3	3	9	1½	4	....	....	3½	7½	1	3½	2	2¼	27	49	2.08	3.77
K	2¼	1½	2	2¼	3½	1¼	½	1¾	2	1¾	2	4½	2½	3¾	1¾	3½	3	12	1½	3½	....	....	3½	6½	1½	3	1½	3	27	48¼	2.08	3.73
L	2½	2½	2	4¼	3½	2½	½	3	2	1½	1½	4	1½	4	2	3	3	9	2	4	....	....	3½	7	2	6	2	3	28	54	2.17	4.15
M	....	....	2	2	2½	3	¾	1¼	1½	2¼	2	2½	1¾	3¾	1½	2¼	....	....	....	....	....	....	....	....	....	....	½	2	12.5	19	1.56	2.38
N	2½	2½	2¼	2	2½	2½	½	2	2¼	2	1½	3	2½	3	¾	3	2½	15	1	3½	2	3	3¼	10	....	....	1½	2	25	53½	1.92	4.11
O	2½	3	2¼	2½	2½	2½	½	2½	2¼	2½	1½	3	2	2½	¾	3	2½	15	1	3	2½	3	3¼	8	....	....	1½	2	25	52½	1.92	4.04
P	2½	3	2¼	2½	2½	3	½	2	2¼	2½	1½	4	2½	3½	¾	5	2½	20	1	5	2	4	3¼	9	....	....	1½	3	25	66½	1.92	5.11
Q	2½	3½	2½	2½	2½	2½	⅓	2	2½	3	1½	3	2½	3½	¾	4½	2½	13½	1	4½	2	4	3¼	8	....	....	1¾	2½	25½	57	1.96	4.38
R	2½	3	2¾	3	2½	3	½	2¾	2½	3½	1½	2½	2¼	3½	¾	4	2½	13	1	3	2	5	3¼	12	....	....	1½	2	25½	60¼	1.96	4.54
S	4	4	1¼	3½	2½	3	1	2	1½	2	2	4½	1½	4½	1	4	2¼	11½	1	4	....	....	3¼	9½	....	....	1½	2	22¾	54½	1.90	4.55
T	4	3½	4¼	4	2½	2½	1	2½	1½	2	2	4½	1½	7½	1	4	2¼	12	....	....	....	....	3¾	6½	....	....	1½	1½	25¼	49½	2.30	4.50
U	4	3	4¼	3½	2½	2½	1	2	1½	3	2	4	2	4¾	1	3½	2¼	10	1	3	....	....	3¼	6	....	....	1½	1¾	26¼	47	2.18	3.92
V	4	5	4½	4	2½	2½	1	2¼	1½	3	2	5	1½	5	1	3	2¼	10	1	3	....	....	3¼	6	....	....	1½	2	26	50¾	2.17	4.33
W	2½	3	1¾	2	4½	3½	1¼	2	1¼	2½	1½	2	2¼	2½	1	2	2	8½	1¾	2½	....	....	4	8½	1	3½	1	2½	25¾	45	1.98	3.46
X	2½	3	1¾	3½	4½	3½	1¼	3	1¼	3	1½	3½	2¼	4	1	5	2	9	1¾	5½	....	....	4	8	1	4	1	3	25¾	58	1.98	4.46
Y	2½	4	2	2½	4½	3½	1¼	2½	1¼	2½	1½	5	2¼	5	1	4	2	9	1¾	6	....	....	4	8	1	6	1	3	26	61	2.00	4.69

TABLE X—*Continued.*

Student's Name	Number of Experiment.																												Total.		Average.	
	1		2		3		4		5		6		7		8		9		10		11		12		13		14					
	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab.	Rpt.	Lab	Rpt.	Lab.	Rpt.	Lab.	Rpt.
Z	2½	4½	2	3½	4½	4½	1¼	3	1¼	3	1½	5	2½	4½	1	4¾	2	9	1¾	6	....	....	4	8	1	4	1	3	26¼	62¾	2.02	4.83
AA	3	5	2¼	4	2	2½	1½	3	3	4	2½	2½	2½	3	½	3	2	8	1	4	....	....	2¾	7	1	3	2½	2½	26½	51½	2.04	3.96
BB	3	4	2¼	3½	2	2	1½	3	2¾	4	2	4	2	4	½	3	2	6	1	3	....	....	2¾	10	1	2½	1½	2	24¼	51	1.87	3.92
CC	3	4	2¼	3	2	3	1½	3	2¼	3½	2	4½	2	4	½	3	2	10	1	4	....	....	2¾	10	1	6	2	4	24¼	62	1.87	4.77
DD	3	4	2¼	3	2	2	1½	3	2¼	2½	2⅛	4	1¾	4½	½	4	2	8	1	4½	....	....	2¾	7	1	5	1½	2	23⅝	53½	1.82	4.11
EE	1½	3	2¼	3½	2	3	1½	3	2¼	3	2¼	3	1¾	3	½	3	2	8	1	3	....	....	2¾	8	1	4	1½	2½	22¼	50	1.71	3.85
FF	3	4	2¼	2	2¼	3	⅓	1½	2¾	3½	1	3½	2	3½	½	3¾	2	10	½	3½	1¾	3½	2	5	....	....	1½	2	21⅚	49½	1.68	3.81
GG	3	4½	2	3	2¼	3	⅓	2½	2¾	4	1	3½	2	3½	½	3	2	16	½	3½	1½	4½	2½	8	....	....	1½	2	21⅚	60	1.68	4.61
HH	3	3½	2¼	2	2¼	2½	⅓	1½	2¾	4	1	3½	2	4	½	1½	2	10	½	1½	1¾	2½	2	4½	....	....	1½	2	21⅚	43	1.68	3.31
II	3	4½	2¼	3	2¼	3	⅓	3½	2¾	3½	2¼	4¾	2¼	4¾	½	5½	2	22	½	6	1½	5	2	10½	....	....	1½	3½	$23\frac{1}{12}$	79½	1.81	6.11
JJ	3	4	2¼	3¾	2¼	4	½	3½	23½	4½	1	5½	2¼	7	½	5	2	14	½	4	1	5	2	13	....	....	1½	3	21½	76¼	1.65	5.87
Total	96¾	130½	87½	109	93¾	107	$31\frac{5}{12}$	84¾	70½	105	57⅞	146½	75½	156½	35	135½	77½	429½	37	138¾	27	72¾	110	305½	15	53½	50	92¾	$865\frac{19}{24}$	2067½	68.23	161.35
Aver.	2.76	3.73	2.43	3.03	2.63	2.93	0.87	2.35	1.96	2.91	1.61	4.06	2.09	4.34	0.97	3.88	2.21	12.26	1.09	4.08	1.50	4.05	3.14	8.72	1.15	4.12	1.39	2.58	24.05	57.43	1.90	4.48

is quite evident that one term-hour is sufficient credit. On the other hand. if all that is done by the student is required to be of a high grade and if to do this he spends 6.38 hours per week as Table X indicates, then he should have more than one term-hour credit.

In studying Table X it should be borne in mind that it represents the condition at one school only. Furthermore, as the course in question was the first course in which carefully prepared reports were required by students, it is probable that they took considerably more time in preparing reports than would be the case in later laboratory courses where they have acquired the ability to write reports quickly and well.

SUMMARY.

In a review of laboratory work. two things stand out strongly: First, what is the function of the laboratory? Second, should students receive more credit hours for the time they spend in laboratory work?

Regarding the first point. the function of the laboratory, it is generally conceded that the experimental work should be so conducted as to illustrate the laws of nature and to fix more clearly in the student's mind those laws which he has studied. Furthermore, the experimental work should serve to train the student to a certain degree in the use of his hands by the manipulation of apparatus and the handling of materials. While he is gaining these two important objects he should be also becoming familiar with the properties of materials of construction.

Regarding the question of more credit for laboratory work, the committee does not feel that it wishes to recommend that more credit be given but desires to have the matter discussed by members of the society. It is quite clear in the minds of some members of the committee that where work is carefully and well done and of a high degree more than one term-hour's credit should be given. But where the work is of low grade a credit of one term-hour is sufficient.

It would seem also not out of place at this time to state that in writing reports much time can be saved the students if there be less duplication of readings or observations. For example, in the study of the elastic curve in the cross-bending test of an I-beam some laboratories require readings and corresponding results for load increments of 1,000 pounds up to perhaps 30,000 or 40,000 pounds. To work up the corresponding points for plotting all of these readings requires a great deal of unnecessary duplication and consequently unnecessary use of the student's time. It is hoped that this illustration may serve as an example where time may be saved the student.

It is the practice at some schools to use alternate laboratory periods for computing results and writing reports. This method requires no work out of assigned hours but if only one exercise is scheduled per week and the course extends over one half year the student receives only about 8 exercises in testing. This is not sufficient if good work is demanded.

Discussion.

Dr. Wm. Kent: I congratulate the committee upon having accomplished something definite and getting it before the Society. I would suggest that the committee go farther and draw some conclusions from the data presented.

I note that in table X the variation in time required by different students for making reports, is tremendous. In one case a student takes three hours for an experiment, and twelve hours for writing a report upon it, a ratio of four to one. In another case a student takes half or two thirds as much time for the report as for the experiment, while in still another he requires from two to three times as much. This shows that something is wrong. I would recommend that the committee plot these figures and see if they cannot arrive at a standard time or standard ratio between the laboratory exercises and the time required to prepare a report on it.

Professor Wm. T. Magruder: The Society is to be congratulated that the committee of which Professor McKibben is chairman has made the statement regarding the amount of time consumed on student reports. A paper was recently presented to the publication committee of the Society in which it was stated that the best student in the class had spent three hours in the laboratory and twenty-one hours on the report, or a total of twenty-four hours of actual time during two weeks, and had received one hour of credit per week. A ratio of apparently twelve to one caused me to inaugurate a time-study of the relation of time spent on laboratory exercises to the credits given. While not yet prepared to report the results, I may say that they are quite surprising, and that I am not yet prepared to accept some of the statements which, though intended to be truthful, are quite unfair, as I think that some of the time reported must have been spent on things not properly chargeable to the exercise in hand.

I suggest that during the coming year each member of each of our committees on laboratory instruction make studies of the amounts of time spent by students in the preparation for, making, calculating the results of, writing out the report on, and correcting the report on, each experiment in his own laboratory. Such studies when collected would yield a quantity of valuable experimental pedagogic data to the members of this Society and to students of education.

Professor A. E. Flowers: A study was made a year or two ago covering all the work in the school of engineering at the University of Missouri. Before the investigation eighteen or nineteen registered hours were required per term. Principally as a result of this investigation the number was reduced to fifteen. The result was secured partly by rearrangement and condensation of courses. For example, courses previously given for three hours for the year were rearranged to be given in five hours in a semester, with the result that what was covered was done in a better manner. Stress was laid on intensive work.

In most cases laboratory reports require a detailed statement of the numerical results of the tests, a descriptive account of the tests and an analysis of the results. In most cases the first represents the actual labor performed by the students in the laboratory, but in a great many cases the descriptive matter represents the accumulated knowledge of the student body. Reports are bound and filed and kept for reference and if the experiments are not changed, the reference text increases annually in volume without increasing in value. There should be some effort directed toward the simplification of reports so that they could be completed in good form during the laboratory period. In my own undergraduate work the most benefit was obtained from the laboratory exercises in which we prepared the apparatus, carried on the experiments and recorded the data and conclusions all within the limits of a laboratory period.

PROGRESS REPORT OF THE COMMITTEE ON TEACHING MECHANICS TO STUDENTS OF ENGINEERING.

Neither the council which suggested the appointment of this committee nor the convention which elected us gave any instructions as to what we are to consider. In the correspondence carried on among ourselves during the year, we assumed that one thing the Society expects from us is a syllabus of the subject of mechanics, resembling perhaps the syllabus accepted a few years ago from the Committee on Teaching Mathematics to Students of Engineering. We assumed also that you would like, in the way of recommendation or otherwise, some expression on certain questions relating to the subject of dynamics which have arisen in past meetings. The last illustration of a discussion of such questions is furnished by the paper presented by Professor Huntington at the Minneapolis Meeting.

We have received a number of suggestions as to special lines of investigation, and as a result several subcommittees have been appointed. One subcommittee is to consider the history of the development of teaching mechanics in this country. Another is to consider the advisability of consulting practicing engineers as to the proper subjects to be included in mechanics. A third subcommittee is to consider methods for improving the quality of teaching in mechanics. That subcommittee consists of the non-teachers on the main committee, Dr. Wm. Kent, Dr. Sanford A. Moss, of the General Electric Company; and Mr. J. E. Wadsworth, of the American Bridge Company; and in view of some publicly expressed opinions of one of the gentlemen named on the quality of mechanics teaching and mechanics textbooks that we have, teachers of mechanics may confidently look forward to some very pointed suggestions on "how to do it" and "how not to do it" from this subcommittee. I hope that the committee will have some recommendations to submit to you next year.

E. R. MAURER, *Chairman.*

DISCUSSION.

Dr. William Kent: I wish to outline, as a contribution to the discussion, the fundamentals of uniformly accelerated motion.

A constant force, F pounds, acts during T seconds on a body containing W pounds of matter, at rest at the beginning of the time but free to move in the direction of the force. It is assumed that there is no frictional resistance.

The results at the end of the time T are:

The space or distance the body is moved, S feet.

The velocity, V feet per second.

The momentum, WV/g.

The Kinetic energy, $\frac{1}{2}WV^2/g$ foot-pounds.

At any instant during the time T, the acceleration A.

The mathematical relation between these several results and F, T and W may be derived as follows:

It is found by experiment that under the conditions stated in the first paragraph, the body moves at an uniformly increasing speed through a distance S in the time T. Since the velocity increases uniformly from O to V the mean, or average, velocity is $\frac{1}{2}V$, and the distance S is the product of this mean velocity and the time, or $S = \frac{1}{2}VT$; whence V, the velocity at the end of the time, $= 2S/V$, and $T = 2S/V$.

The velocity V, in feet per second, is numerically equal to the number of feet the body would travel in 1 second after the expiration of the time T if the force had then ceased to act and the body continued in motion at a uniform velocity unimpeded by friction or other resistance.

It is also found by experiment that the value of V is expressed by the equation

$$V = \frac{FT}{W} \times g, \tag{1}$$

in which g is a constant number, 32.1740, which is the velocity in feet per second, that a falling body would acquire in one second if it fell in vacuo at latitude 45° at the sea level (called the standard of locality).

From this equation it is seen that the velocity varies directly as the force and as the time, and inversely as the quantity of matter. If $F = W$ and $T = 1$, as in the case of a falling body under the conditions named, then $V = g$.

If in equation (1) we substitute for V the value $2S/T$ we obtain

$$S = \frac{FT^2g}{2W}, \tag{2}$$

an expression for the distance traversed under the condition named in the first paragraph.

By transposition, equation (1) may be made to take the forms $WV = FTg$, whence we obtain

$$FT = \frac{WV}{g} \tag{3}$$

and

$$F = \frac{WV}{Tg}. \tag{4}$$

If in these equations we substitute the letter M for W/g we have $FT = MV$ (5) and $F = MV/T$ (6).

The name "momentum" is given to the product MV or WV/g.

Substituting for V/T the letter A, called the "acceleration" we have $F = MA$ (7) and by transposition $A = F/M$ (8).

The acceleration is the rate of change of velocity from O to V during the time T. If V = the velocity at one instant and V_2 the velocity at another instant t seconds later, then the acceleration is $(v_2 - v)/t$.

If in equations (2) and (4) we substitute for T its value $2S/V$ we obtain

$$FS = \frac{\frac{1}{2}WV^2}{g} = \frac{1}{2}MV^2. \tag{9}$$

or the "kinetic energy," which is numerically equal to the product FS, in foot-pounds, of the force into the distance through which it acts, or the work. Work, $FS =$ kinetic energy, $\frac{1}{2}MV^2$.

Tabulating the above results we have:

Distance or speed, $S = VT/2 = FT^2g/W$.

Velocity, $V = 2S/T = FTg/W = AT$.

Momentum, $MV = (W/g)V = FT$.

Kinetic energy, $\frac{1}{2}MV^2 = \frac{1}{2}(W/g)V^2 = FS =$ work.

Acceleration, $A = VT = F/M = Fg/W$.

Force, $F = WV/gT = MV/T = MA$.

Matter, $W = FTg/V$.

$M = W/g$. $g = 32.1740$.

Force of Gravity in Different Localities.—At latitude 45° at the sea level the acceleration of a body falling freely, called "the acceleration due to gravity," is 32.1740 feet per second in each second (often called feet per second, or feet/sec.^{2}). At other latitudes and elevations, the acceleration varies according to the formula $g = 32.1740 - 0.082$ cos. 2 latitude $\times$ 0.000003 height in feet.

At Philadelphia, lat. 40° $g = 32.16$,

At the equator at the sea level, $g = 32.09$,

At lat. 60° at the sea level, $g = 32.22$.

For all ordinary engineering calculations g may be taken as equal to $g = 32.2$, a sufficiently close approximation, but for precise calculations for any particular locality, the local value of g, and the corresponding value of the force of gravity acting on a pound of matter should be considered, provided the local force of gravity is an element in the problem. (Examples: Spring balance; lever safety valve; lever testing machine; falling bodies.)

The force with which gravity attracts a body is proportioned to the acceleration. At lat. 45° at the sea level the number of pounds of force F equals the number of pounds of matter W. At any other locality $F = W(g_1/g)$.

Falling bodies.—Equations (1) and (2) apply viz.: $V = FTg/W$; $S = FT^2g/W$. The letter H is commonly used instead of S to represent the height of fall. At lat. 45° at the sea level $F=W$, and we then have $V=gT$; $H=\frac{1}{2}gT^2$. Substituting for T its value $2H/V$ we obtain $H=V^2/2g$; $V=\sqrt{V2gH}$.

These are the general equations for falling bodies, and for all ordinary calculations g may be taken at 32.2, but for precise calculations the local value of g should be used.

Force Acting on Bodies in Motion.—If a body at a given instant has a velocity V, and a force acting on it during T seconds thereafter in the direction of the motion, giving it at the end of the time a velocity V_2, the mean velocity is $(V_1+V_2)/2$ and the distance it travels during the time T is $(V_1+V_2)T/2$.

The acceleration or change of the velocity is $(V_2-V_1)/T$. The momentum MV_2 and the kinetic energy $\frac{1}{2}MV^2_2$ are the same as if the original velocity V had been O.

If the form acts in the opposite direction to the motion, the same equations apply, but V_2 will then be less than V_1 and the acceleration will be negative quantity, or a "deceleration." If a body is moving vertically upwards against the force of gravity, with a velocity V at a given instant, that velocity will be reduced to O in the same time and in the same distance that a body would fall to secure the velocity.

Weight.—The quantity of matter W, as weighed in an even balance or lever scale at any place, or on a spring balance calibrated so as to register pounds of matter at the place where the weighing is done, is commonly called weight, and it is a constant quantity for any given body. The word weight is also given to the force in pounds with which gravity attracts a body at lat. 45° at the sea level or at any place where the acceleration due to gravity is 32.1740 feet per sec. per sec. Since the number of pounds of force with which gravity attracts a body at the standard locality is the same as the number of pounds of matter the body contains, no confusion need result from the use of the term weight or of the symbol W in this double sense. When we say "this piece of iron weighs four pound weight," or "this piece of iron weighs four pounds'' we mean by either of these expressions both that the quantity of matter in the piece is four pounds and that the force with which gravity would attract it at the standard locality is four standard pounds of force, a pound force being defined at that force, which, acting on a pound of matter for one second will give it a velocity of 32.1740 feet per second, or that form which will give it an acceleration of 32.1740 ft. per sec. per sec.

Local Weight.—The term ''local weight'' may be used, if desired, to signify the force with which a body is attracted by gravity at another than the standard locality. In such a case the value of g for that locality should be stated.

Mass.—The word ''mass'' is commonly used in works on physics to mean quantity of matter (in pounds, kilograms or grams), the word weight being confined to the meaning of the force with which gravity attracts a body, this force varying with the location. By some writers the quotient W/g is called mass, and it is regarded merely as a quotient or mathematical expression, represented by the letter M for convenience. In this case W is either the quantity of matter in pounds and g a constant $= 32.174$, or else W is the force with which gravity attracts a body at any given place and g is the acceleration due to gravity at that place. In either case the quotient W/g is a constant for a given body. By others mass is called quantity of matter, not in pounds but in a new kind of unit, not known in commerce or in engineering, to which the names ''engineers' unit of mass,'' ''gee-pound'' and ''slug'' have variously been given. In the C.G.S. (centimeter-gram-second) system, mass is quantity of matter in grams, but force is measured not in grams but in dynes (1 dyne = the force that gravity exerts on 1 gram at lat. 45° at the sea level, or the force that gives 1 gram an acceleration of 1 centimeter per sec. per sec.). Many writers of text-books on physics have attempted to imitate the C.G.S. system in English units, inventing a new unit of force, the ''poundal'' $= 1/32.174$ pounds of force.

On account of the varied and confusing use of the term mass, it is recommended that it not be used to mean quantity of matter in pounds, and that when it is used to mean the quotient W/g its meaning should be clearly explained.

The equation $F = MA$ is often read "force means mass times acceleration" but this reading of it is not true if F and M are both measured in pounds. It is true if it is understood that F is in pounds and that M always means the quotient of W (quantity of matter in pounds) divided by 32.174. It is also true if M is mass in grams and F is force in dynes.

The terms "engineers' unit of mass," "gee-pound," "slug" and "poundal" should be expunged from the text-books and to fall into oblivion.

The expression found in many text-books that "force is mass times acceleration" and "force is the time rate of the increase of momentum" should also be omitted from the text-books. Force is not either of these things, it is only numerically equal to them when certain units are chosen. The symbol "=" should not be translated "is." Force should be defined as a pull or push, and its units, the pound, as that force which gives a pound of matter an acceleration of 32.1740 ft. per sec. per sec., which is the force with which gravity attracts a pound of matter at 45° at the sea level.

REPORT OF THE COMMITTEE ON TEACHING PHYSICS TO STUDENTS OF ENGINEERING.

It is impossible at this time to make any definite report. The committee has had only informal consultations; in fact it is somewhat embarrassed by its inability to formulate a plan of investigation that will lead to results of definite value. The teaching of physics has been considered by this Society for many years, and the PROCEEDINGS contain papers, reports, and discussions upon all phases of the subject; it seems almost superfluous to undertake further study. The informal consideration has suggested several topics which will be mentioned, and the Committee earnestly desires that the present brief discussion take the form only of suggestions for the work and not of criticism of anything that may be mentioned in this preliminary report.

It may be possible to prepare a generalized syllabus of physics for engineers. There are certain fundamentals which the student should master, and he should acquire a certain degree of familiarity with a considerable number of other subjects which may be called related subject matter. The fundamentals should be thoroughly taught to all students, but the amount and choice of related subject matter, methods, and order of teaching both fundamentals and related subject matter should be entirely in the hands of individual teachers. An important question is this: Should students in the several engineering courses have different amounts of instruction in the several branches of physics; for instance, should the course for civil engineers differ from that for electrical engineers?

Related to this is the determination of the amount of time to be devoted to general physics, and the selection of subjects which can be turned over to other departments, such as applied mechanics and steam engineering. It is possible also that the nature of treatment desired in a text-book may be possible of definition as well as the relative amount of space to be given to each subdivision. The amount of time, if any, that should be given to things not strictly utilitarian might be discussed.

Perhaps it is necessary to acquaint the engineering departments with exactly what has been taught in physics, thus saving time in needless repetition. I personally know that when a head of a department asks a student if he knows certain physical facts, the student sometimes denies that he knows anything whatever about them. The physics department is, therefore, blamed for omitting so important a subject, when in fact it has been adequately treated, but has been carelessly passed by the student.

The dangerous tendency, shown in some engineering schools, to curtail the general physics course in order to substitute departmental technical work requires attention. The content of the course in physics necessitates careful consideration of the laboratory work in relative amount and its relation to engineering. And incidentally, because the "administrative methods" referred to by other speakers, justice to both the student and the teacher of physics requires that proper allowance be allowed for laboratory work in counting "units" of work. The common method of rating three hours of laboratory work and the writing of a report as equal to only one hour of recitation or lecture work is grossly unfair.

The committee might further make some suggestions as to laboratory equipment; whether for example, it is desirable to have a standard form of instrument, such as a galvanometer or a spectrometer, which is duplicated as many times as required or whether it is better to have instruments of all styles. In the use of instruments also there is a question as to the degree of accuracy to be demanded in ordinary laboratory work and as to the style of report to be required.

Perhaps it is proper to consider preparatory school physics teaching. There is a tendency to include certain engineering experiments and technical processes in preparatory school physics which may be regarded as having an influence for good or bad to the student after he reaches college.

The teaching of physics to engineers requires instructors who are not only well informed in physics, but who also appreciate applied science and who have enthusiasm for real teaching. The rather widespread tendency to choose only the candidates who have secured the doctor's degree in physics often brings together a poorly prepared teaching staff so far as engineering physics is concerned. The head of a department is naturally desirous that his laboratory shall turn out a large amount of research work, as shown by published papers. This work is usually given wide publicity, while the poor teaching and often neglected classwork of the instructors is rarely known even within the institution where it occurs. Even an engineer should be trained in a college atmosphere charged with the inspiration of original investigation, but the young instructor who has had only academic training in pure science, and whose teaching is controlled only superficially may often slight the engineering teaching for his own research. These facts lead to the opinion that there should be certain courses leading to the doctor's degree in which greater respect and enthusiasm for engineering teaching shall be inculcated.

It may be desirable to choose for the instructor in engineering physics in place of the doctor of philosophy, a bachelor of science who has spent two or more years after graduating, in engineering practice. Such an instructor need not be expected to produce original papers in pure science, but he may well develop new work of real value in applied science, such as better methods of experimentation, or improved instruments for technical measuring. For instruction in advanced theoretical physics, and for research assistants, the doctor of philosophy must still be chosen.

The committee may further inquire whether practical shop experience and discipline facilitate the study of engineering physics. If it is considered desirable, such shop work could be required as part of the course of study. It could be taken in the summer vacation, or scheduled like other studies.

The committee proposes to formulate its report upon its own deliberations and also upon a much disliked questionnaire. Since the Society appointed the committee it feels at liberty to impose the questionnaire upon the members.

D. C. Miller, *Chairman*,
G. V. Wendell,
J. M. Jamieson,
W. S. Franklin,
H. M. Raymond,
O. M. Stewart,
E. P. Hyde,
G. A. Goodenough,
F. K. Richtmyer.

Discussion.

Dr. Wm. Kent: I have had some experience with teachers of physics. At Syracuse University we had a splendid teacher of physics. He not only knew how to teach, but he also excelled in research work. In spite of this fact, the professor of electrical engineering complained that the students coming to him as juniors to learn electrical engineering did not know what volts and amperes were. I advised him to write twenty questions on engineering fundamentals chosen to cover all that a student should know of physics to enable him to take up electrical engineering. With such a set of questions it is perfectly fair to expect him to know the answer to them perfectly. The professor of electrical engineering prepared the questions and his colleague in physics was delighted to get them. He said, "That is fine. Now that I know what you want I will teach it to them." It is a good thing to get after the professors of physics and tell them what to teach.

A professor of physics once asked me to write him a sample question of the kind which I have been advocating for some time. This is the result. "Given a square foot of steel plate one quarter inch thick, with hot air on one side of it and cold air on the other, or with steam on one side and water on the other; required the number of units of heat that would pass through the plate in an hour?" The professor said that he could not answer that question himself. He could not do so because he had not experimented along that line. I suggested that he get up some experiments of this kind in heat conductivity. Physicists need no suggestions like this. Not how to teach but what to teach.

Professor D. C. Jackson: I want to ask Professor Miller one question, in view of the fact that engineering is associated with new problems, essentially of the character of physical research. Why did he make the statement that "*even* the engineering students may profit from the stimulating atmosphere of electrical research?" I want to bring up the suggestion that the committee alter its point of view, if that statement was ironical.

Professor Miller: I think most of the teachers of general physics feel that the statements which I have made are often true of students of engineering. I find that the engineers want utilitarian physics.

Professor Jackson: I will support the proposition of Professor Miller if he will add this to his statement: "The engineering students *need* the stimulating atmosphere of physics and research."

Professor Miller: I shall be glad to do so. I agree with it.

Professor V. Karapetoff: Professor Miller mentioned utilitarian physics, which he says is required more and more in engineering schools. This is certainly one of the signs of the times. One hears this question asked more and more, "Why teach pure physics? Why not let our instructors in engineering teach whatever utilitarian or applied physics we need in our engineering colleges? Why not do away with the preparatory work in pure physics?"

However radical such a proposal may seem, I fear that it is the trend of the times. Formerly we were satisfied with mechanics as taught in physics. Now, most of the technical schools have substituted courses in engineering mechanics, teaching it in a utilitarian way. And we shall hear more and more questions asked like these: "Why teach the fundamentals of heat under teachers who know nothing about a gas engine or a steam engine? Why not give all of this instruction in connection with heat power engineering? Why teach about volts and amperes and a lot of similar ideas in physics, when we can do this better in connection with our courses in electrical engineering?" I must reluctantly admit that enough pressure will be gradually brought by teachers of engineering to force the study of physics in connection with heat engines and electrical apparatus. Such is the result of the great expansion of the engineering profession, preparation for which requires more and more time and greater efficiency of instruction. I shall deplore greatly this change unless there is provided a course in pure physics during the senior year. Having learned the elementary laws of heat and electricity in the engineering department, let the advanced students go to the department of physics to get the inspiration of exact measurements and learn the methods of pure original research. I think both engineering and physics would profit by such a change.

Dean Anthony: I think that there is a misconception in regard to teaching, namely, that when a subject or an answer to certain questions has once been properly taught and thoroughly learned that it is always known. As a matter of fact, it is only by repetition that these matters are thoroughly learned. This fact has an important bearing upon the present discussion.

PRELIMINARY REPORT OF THE COMMITTEE ON COÖPERATION WITH SECONDARY SCHOOLS.

In educational circles, where formal hearings are not practicable, much time is required for the collection of statistical matter and also of professional opinion. Your committee on coöperation with secondary schools, although it has been in existence for more than a year, is not yet in a position to report any formal conclusions, but requests an extension of time in which to continue its investigations, and presents at this time a report of progress.

It may not be out of place, however, at this time to present for your consideration a statement of the aims and purposes of this committee. The committee was appointed in response to what appeared as a greatly increased interest in the proper scope of function of the American high school on the part of those who are engaged in the work of higher education. Until recently, high schools were regarded chiefly as *preparatory* schools, whose aim it should be to bring a limited number of young men and women to that stage of intellectual development at which they might properly begin work in higher institutions of learning. The attainments of these young persons were to be tested by examinations covering a wide range of topics. High schools were judged according to the number of students passing these examinations, which constituted practically the sole link between the lower and the higher institutions.

The past few years have witnessed a decided change from this point of view. In the first place, it appeared that these examinations, while quite rigidly adhered to as matters of form, were seriously distrusted as criteria of proficiency. Many institutions preferred to rely rather upon an experimental freshman year, admitting students quite freely, and dispensing with their presence with equal facility in a short time. Then it was noted that there was a type of student who is always ready at examination time, but whose mind is responsive only to the formal question, and not to the needs of a situation, an "examination shark," as he is sometimes termed. Again it appeared difficult, if not impossible, to frame a satisfactory examination upon the broader aspects of a subject, rather than upon the relative intricacy with which its parts were involved. Again, note was taken of the fact that the undergoing of a searching mental examination in a variety of subjects at the age at which the average student leaves high school is often not a suitable experience for him. Preparation for it is likely to take on too much of the character of grooming for one of the events of a lifetime; the test itself often results in distressing nervous reactions; and the successful passing of the examination creates in the mind of the student the impression of work completed, when really he should consider it as hardly begun.

Finally, it became necessary to take cognizance of the fact that the large majority of students in high school do not go to college at all, nor have they any intention of so doing. The high school is rapidly coming to relate itself directly to the future lifework of its students, without the intervention of a more advanced institution of learning. In consequence, profound changes in curriculum and method are under way, which point directly away from the generally accepted notion of college requirements.

At present, the *certifying* of students by high school authorities is gradually taking the place of entrance examinations. The results thus far, in institutions where both methods of admission are used, indicate quite clearly the superiority of the former mode of procedure. But the certifying of a student calls for a written statement to the effect that he has spent a stated amount of time in the study of each of a large number of prescribed subjects, including possibly a few electives. This prescription, when followed, governs practically the whole of a student's high school career, and if due regard is paid to economy of time, demands that he enroll in a so-called "college-preparatory course" when he enters the high school, to the exclusion of a considerable field of work which the school must offer in response to popular demand. It is, however, well known to teachers and others that a very large percentage of students do not disclose or discover for themselves their own special aptitudes until they are well on toward the close of their high school experience; that very often that particular facility in the acquisition of knowledge which is essential to success in advanced work does not appear until relatively late; and that in many cases the formation in high school of correct habits in mental activity is of infinitely greater worth than any half dozen specified "counts" that can be named.

These last-mentioned considerations have had little effect on the actual state of the case. But there has come to prevail among teachers of high and low degree the sentiment that college preparation is neither the successful completion of a stated number of "hours" of high school work, nor the passing of a specified number of examinations, but a *state of mind*. How properly to bring this mental condition into being, and how to recognize its existence when it arises is the problem that is laid before your committee.

This is a large problem, and one not likely to be solved overnight. It reaches to the limits of our entire educational system. It is fitting, moreover, that this problem should be considered by a society of engineers. The genius of engineering is the spirit of this age. Within a comparatively few years the control of industry has largely passed into the hands of the operating departments. Even human activity, the personal element once so loudly proclaimed as of free and independent agency, has been found to be subject to the laws of economy of time and effort. "Efficiency" is the watchword of the day. If education is to be efficient in any true sense of the word, it must be so from bottom to top. In a word, education in this country is in need of being properly "engineered."

Though the committee cannot report completely, it is ready to enter a plea. This is, to paraphrase the immortal "Speech on Conciliation," for the admission of the high schools into an interest in the educational constitution. This means a number of things.

First, it means a widespread recognition of the worth of high school training for its own sake. It means that there is a well-defined place in our industrial and social fabric for the man who is *partly trained.* It means also that inability to attend a higher institution, or to remain there for the prescribed four years, should not necessarily count as failure.

It demands, however, that secondary training and advanced training of the first years in college should be of high grade so far as it goes. To the furtherance of this end, it asks for a deep conviction on your part of the importance of public education generally; increased salaries for those who are engaged in this work; correspondingly higher standards set for those who are about to enter the teaching profession, both in high school and college; and the scientific management of schools.

Second, it means a growing willingness to accept at its face value the judgment of a high school teacher as to the ability of his pupils. It is too much to expect that for some time to come the American high school teacher shall obtain the recognition which is accorded to the professor in a French lycée or a German gymnasium. But there is a moral side to this demand. If the student who has been certified into college is on the whole making better progress than the one who has entered on examination, may it not be because in the case of the former his teachers felt keenly their responsibility for his whole future career and acted accordingly, while in the case of the latter, their responsibility ended when his entrance examinations were completed? And may it not be possible that, within certain limitations, a student who has entered largely on his teacher's judgment as to his general ability would really be still better prepared for further progress?

Third, it means the elimination of that waste between the lower and higher institutions which is at present involved in the repetition of numerous topics in mechanical drawing, manual training, mathematics, physics, and chemistry. It is to this task that the committee has addressed itself, with the general idea that these subjects all have their lower and higher aspects which should be definitely delimited. Professor Clifton is at present investigating high school and college work in physics from this point of view. Professor Rondinella has been for some time at the same task in the field of mechanical drawing, and will present his views in a separate paper. Professor Wirick will report on the situation in the department of chemistry; and to the chairman has fallen the lot of drawing certain distinctions in the field of mathematics.

In this field it may be proper to state that there is a well-defined need for the standardizing of mathematical problems. This might follow along three lines; the relative difficulty of the underlying concept, the number of distinct operations entering into a particular problem, and the extent of its field of application. It would appear that a college course embodying certain principles and types of problem in elementary algebra, elementary, plane and solid geometry, and trigonometry, might well follow a high school course embodying some portions of the analytical geometry and the calculus; but sufficient data are not now at hand to justify this view as conclusive.

It is the desire of the committee to keep in close touch with the special committees of the society in the various subjects referred to.

On the larger aspects of the high school problem, the harmonizing of the avowedly selective methods of the higher institutions with the general educational purposes of the high schools, the efficient distribution of time and effort in high schools, and the relative merit of a frankly partial, as opposed to an exhaustively thorough training in a particular profession, all the membership of the committee is at work and these it wishes to emphasize today. Is it too much to ask that for a time the Society for the Promotion of Engineering Education should become a society for the promotion of educational engineering?

H. E. Webb, *Chairman,*
H. T. Clifton,
L. F. Rondinella,
C. M. Wirick.

CONSTRUCTIVE DRAWING IN HIGH SCHOOLS AND ENGINEERING COLLEGES.*

BY L. F. RONDINELLA,

Professor of Constructive Drawing, West Philadelphia High School for Boys.

Most of the engineering colleges complain that students entering from many of the high and preparatory schools have had no instruction in drawing; and many of the manual-training or technical high schools complain that their graduates entering colleges are given no credits for courses in drawing that in some cases amounted to as much as four hundred hours of classroom work. We believe that our engineering colleges would be justified in adding to their entrance requirements at least one hundred classroom hours in constructive drawing, including instruction in the care and use of the ordinary drafting instruments, and practice in the best conventional methods (which this Society might adopt and recommend) applied in the preparation of simple working drawings. We believe that for such elementary instruction in drawing, the schools should be given by the colleges, entrance credits equal to those allowed for the same number of hours in science laboratory work, or three-fourths of the credits allowed for instruction in mathematics.

We therefore recommend that the preparatory schools should be requested to cover thoroughly the following ground in teaching drawing:

A review, with emphasis on the exact meanings, of the geometric terms used to describe the different kinds of lines, angles, surfaces and solids.

An understanding of, and a familiarity with, the machine-draftsman's units of measurements; the unit for measuring lines (the "length" or "distance-interval" unit) to be the inch only, with its common fractions; and the unit for measuring angles (the "direction-interval" unit) to be the degree only, with its common fractions.

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* Supplementary to the preliminary report of the Committee on Co-operation with Secondary Schools.

Practice, to gain facility, in the use of the ordinary instruments for accurately drawing and measuring lines and angles; straight lines to be measured especially by scales of full, half, quarter or eighth-size inches; and angles to be plotted and measured especially by the two single triangles (or one simple combination instrument) capable of plotting all multiples of fifteen degrees.

Inking-in exercises, to combine with the above some practice in neatly forming the six different kinds of lines conventionally used on a working drawing,—as specified under "conventions" below. (The graphic solutions of plane geometry problems are not recommended for drawing exercises.)

A clear explanation of the differences in the two methods of expressing the shape of a solid object, (*a*) by the one view of a picture drawing, and (*b*) by the two or more views of a working drawing. For (*a*) it is not recommended that the theories of linear perspective should be explained or applied; but that the teacher (with the aid of a blackboard drawing showing the eyeball containing its crystalline lens and retina, and having a rectangular surface of some exhibited solid drawn in front of the eye) should explain how we see an object or get a mental picture of its shape. He should represent the rays of light that are reflected from all visible parts of its surface in straight lines, converging so as to meet and cross in the lens, and continuing to the retina where they form the image or impression of shape that is transmitted through the optic nerve and received by the brain. He should show that the rays reflected from a near line of the object will form a larger visual angle and therefore a larger image than the rays from an equally long line that is further away; and should demonstrate that we will therefore not see the *fact* of shape, but that equally long parts will appear shorter when further away, parallel lines will appear to converge as they recede, right angles in a receding surface will appear sometimes acute and sometimes obtuse, etc. The teacher should then draw on the blackboard a pictorial view of the exhibited solid so as to impress on his students that a picture is a single view of the object so drawn on one plane surface that it will convey through the eye the same impression of shape that would be conveyed from the several surfaces of the object itself when viewed in a similar position; it expresses the appearance of shape, but does not give any information *per se* regarding the size of the object. For (*b*) it is not recommended that the theories of orthographic projection should be explained; but that the teacher, with the aid of a model (*e. g.*, a rectangular prism with a square hole through its largest faces) and a geometric view of it on the blackboard, should explain that, in order to see the facts of shape and relative size, we assume the rays of light to be reflected from the object in parallel (instead of converging) lines,—an assumption that cannot practically be realized except by moving the eye or moving the object so that each part of it is viewed in the same direction. He should show that, under this assumption, a near edge of the object would appear to have just the same length as an equally long edge that is farther away; that we can see the true proportional lengths of lines, or the true sizes of angles, or the true shapes of surfaces only when they are parallel to the observer, or when he views them at right angles; that not more than two of the three perpendicular (length, breadth and thickness) dimensions in a solid can be parallel to the observer at one time; that in order to see all the facts of shape we must therefore view the object in at least two different directions, and to express these facts graphically we must have at least two geometric views of the entire object in our constructive drawing. These views show relative or proportional sizes; they may be larger than the object (as in a blackboard drawing), or of equal or smaller size (as in most paper drawings). To express definitely the facts of size, the dimensions in inches are entered on the views in conventional ways that the teacher will explain and demonstrate by a working drawing on the blackboard. He should impress upon his students that a complete working drawing should contain:

1. As many geometric views of the object as are necessary to express completely the facts of its shape and construction; at least two views.
2. All the dimensions that are necessary or desirable.
3. The title, or name of the object.
4. The scale, or proportion which the lines of the drawing bear to the corresponding edges of the object.
5. The notes, or additional necessary information as to the number needed, the material, the surfaces to be finished, etc.

With the above foundation firmly laid, the students in preparatory schools should be taught to make practical constructive drawings of familiar objects and simple parts of machinery, both freehand and mechanical (instrumental). The freehand sketches can best be made by the student in his blank-book (1) while the teacher is making and explaining a free-hand sketch at the blackboard; (2) from a verbal description or specifications; (3) from the object itself, and (4) from a mechanical drawing. This freehand work has considerable educative value if taught so as to train the student's eye in judging proportions, and to train his hand in rapidly drawing lines with approximate but increasing accuracy. The student's mechanical drawings should be accurately made with the aid of all necessary instruments; (1) from his own freehand sketches; (2) from sketches prepared by his teacher or included in one of the good published collections; (3) from the teacher's dictation with an illustrative blackboard demonstration, and (4) from written specifications. The mere copying of other mechanical drawings or plates should be discouraged, as it has little educative value; and being usually given without much teaching, it develops a technique which is often incorrect and has to be changed in subsequent engineering instruction.

Your committee feels that it would be an immense help to engineering education and engineering practice if the same conventional methods, lines and symbols could be used by the preparatory schools, the engineering colleges, and by engineers' drafting rooms in preparing working drawings of machinery. We therefore suggest, for adoption and recommendation by this Society, the following conventions as being in accord with modern practice in a majority of the best drafting rooms.

The geometric views to be placed on the sides of each other to which they refer,—*e. g.*, a top view above, and a right end view to the right, of a side view,—the "third angle" method of descriptive geometry. We recommend this also for more consistent use in architectural drawing, where the plan (or top view) should be placed above the elevation (or side view).

In mechanical (*i. e.*, instrumental) drawings, the views to be made and dimensioned with the use of four (sometimes five or six) different *conventional lines*, as follows:

1. A fine, continuous line to be used for dimension-lines, and for the end-lines of dimension-lines that are placed outside of the parts of the view to which they refer.

2. A continuous line of medium weight to be used for the visible edges of the object that are not represented as casting shadow.

3. A medium weight, so-called "dotted" line, but consisting of dashes about one sixteenth inch long with spaces about one thirty-second inch between them, to be used for invisible edges of objects.

4. A medium weight, so-called "dash-and-dot" line, but consisting of dashes alternately about one half inch and one sixteenth inch long with spaces about one thirty-second inch between them, to be used as a center-line or axis of symmetry for the view or part of a view that they cross; and also as a section line through which a cutting plane is assumed to be passed at right angles to the view.

5. A thick, continuous line to be called a "shade-line" and to be used for those visible edges of the object that would cast shadow under the conventional assumption that parallel rays of light strike the object from above, and the left and the front

at 45 degrees to the horizontals, the verticals and the plane of the view. In addition to indicating those edges which would actually cast shadow, shade lines should always be placed on bottom edges if horizontal or slanting upward and to the left at less than 45 degrees and on right-hand edges if vertical or slanting upward and to the left at more than 45 degrees, *e. g.*, the outside edges of curved surfaces. Shade lines tell the reader of a drawing that the surfaces above and to the left of them are higher than the surfaces below and to the right; and while they are helpful in understanding the shape of the object, and sometimes prevent the necessity of an additional view, they are omitted in some good drafting rooms.

6. A medium weight, so-called "dashed" line, consisting of dashes about one fourth inch long with spaces about one thirty-second inch between them, to be used in showing the construction of some part that must be graphically developed.

Dimensions to be expressed in inches and degrees by plain Gothic numerals placed in a break of the dimension line where it does not cross another line. The numbers all entered to read one way, *i. e.*, with the bottom of the numbers toward the bottom of the drawing, and all fraction-lines horizontal. The inch symbol may be omitted after the numbers if included in expressing the scale, *e. g.*, "scale, half-size inches."

Cross-hatching on plane surfaces in section to consist of medium, continuous, oblique lines, equidistant about one sixteenth inch in the horizontal direction. Each different piece in any one view to be cross-hatched in a different direction, in the following order of preference: 45 degrees up-to-right, 45 degrees down-to-right, 60 degrees up-to-right, 60 degrees down-to-right, 30 degrees up-to-right, 30 degrees down-to-right. The material of each piece in section to be printed in a clear spot left in the midst of its hatchings, or to be stated in the notes printed under the title.

Lettering to be printed in plain printers' Gothic or its modifications suggested by Reinhardt or Daniels. In penciling the freehand letters on mechanical drawings, three horizontal guide-lines should be drawn lightly to establish the heights of capitals and small (printers' "lower-case") letters, —the latter being about three-fifths as high as the capitals. In using single-line Gothic capitals in finished titles, the widths of letters and spaces should first be added and then measured on the drawing when the length of each line of lettering is to be centered; the outline of each letter should be blocked in pencil; compass centers should be accurately located for the curves; and the letters inked instrumentally. For large titles, map and chart work, the block-letter alphabet should be taught in its simple straight-line form, with all letters five blocks high, and each letter three blocks wide, except the "I," one block, the "M," four blocks, and the "W," five blocks. With this alphabet first studied and made in square blocks, the student should be taught some of its infinite varieties possible by modifying the shapes of its blocks. He should be shown how it can very easily be modified into the alphabet of open-face or double-edged Gothic capitals, by substituting circular arcs in those letters having corners cut off by diagonals. The student's lettering should be supervised carefully from the start, since practice in forming the letters wrongly establishes habits very difficult to correct.

Finally, the preparatory schools should be impressed with the fact that constructive drawing has large educative value if taught so as to train simultaneously the student's brain, and his hand, and his eye; and that this threefold training will be of subsequent use to him whether or not he applies it technically in a drafting room or in an engineering course of study.

Discussion of Report of Committee on Coöperation with Secondary Schools.

Dean G. C. Anthony: I believe that the committee which has just reported is one of the most important that can exist in the Society because the educational value of our work is based on the work done in the secondary schools to a very great extent. If we desire to help our colleges and technical schools we must help in every way possible the work of the secondary schools by the closest corperation.

Professor C. M. Wirick: I desire to state some of the conditions under which the secondary school teachers work, and then see if we can get assistance in changing them for the better. In the school where I teach, any pupil who finishes the eighth grade enters the high school automatically, if he so desires. He enters on what is called his "general average." that is, on reading, arithmetic, and language. In any one of these the grade may be down to 25 or 30 per cent., but if the general average is satisfactory the pupil enters high school.

The grammar schools are overcrowded, as the principles are jealous of each other, each endeavoring to get all the pupils he can in his school, as his salary depends somewhat on his doing so. We are expected to take this large number of boys and to turn out students whom the colleges will accept.

There are members of this Society who would tell the secondary school teachers what to do, and how to do it, and yet they would not accept the results of their advice and suggestions if we followed them. Moreover, much of the high school teaching is now done by college trained men who detect readily this two-sided attitude. We are supposed to prepare boys for college, but during the four years that they spend in the high school, college entrance requirements cannot be made the primary consideration. We are training them to live, and if one college does not take our graduates another will. I have heard that there is competition even among the colleges for students.

It is discouraging to have the colleges tell us that we must not teach physics as they do not allow credits for it, that they would sooner have the students without it. The result is that a number of young men think that the only good teachers are in college. Some of these men may not be glad to find that boys to whom they taught physics in one year do not know anything about it the next year.

We high school teachers object to the entrance examination seriously. It is the test that makes the student's chance of spending four years in college depend upon a few hours work under conditions that tend to nerve strain; as proved by the percentage of its output which can stand these examinations. We think that our objection is worthy of some consideration.

In my own work I teach chemistry to high school boys. When they come to me they have had shop-work, drawing and physics. I use chemistry as a means for teaching boys without a thought of any college. When these students were admitted to college by certificates, they were compelled to repeat their chemistry, a sheer waste of time. When I protested to the head of a college chemistry department, he replied, "I like your nerve," and he did nothing. To show, however, that these boys are intelligent, I would state that there is an honor for efficiency, and of the seven who secured this, three were my students. I am pleased to state that the institution to which these boys went now gives credit for high school chemistry. This should be done more generally.

College teachers give up the idea that they are the only teachers. They should give the boy a fighting chance, without making their careers depend upon two days' examinations.

I want to suggest that a committee of technical teachers be appointed to take up these matters with us, not for the purpose of blaming us but to better conditions. If we all play fair, such a committee will do far-reaching and important work which may redound quite as much to the benefit of the secondary school as to the college.

Professor G. R. Chatburn: I appreciate the problems of the secondary school teacher for I began my teaching experience in a little country schoolhouse, afterwards taught in the high school, later was superintendent of city schools and finally went into the engineering college as a teacher. Referring to the recommendation of our committee on secondary schools I believe that it will not be possible in our western colleges at the present time to require a course in drawing such as has been suggested. The men composing this committee are secondary teachers and principals of high schools in the larger communities. They must not forget that we have in Nebraska and in other states, a great many high schools whose graduates must go into the universities, which cannot give satisfactory work of this kind. The instructors at this meeting do not appreciate the troubles of the teachers in the little towns. There are many small high schools that are trying to carry a four-year course with perhaps not more than four teachers. These teachers, as a rule, can teach such subjects as Latin, algebra and geometry satisfactorily. But if we ask them to give a course in drawing, such as was outlined, I think many of them would not furnish us satisfactory students. It is preferable that they teach those subjects which they can do well and let us teach them such subjects as drawing after they enter college. In Nebraska there are a few high schools in cities such as Lincoln, Omaha and York, where they give satisfactory training in drawing and manual training. From such schools we accept the credits to cover entrance requirements, and the students are excused from taking elementary drawing in the college, but they are required to take another subject in its place, so that they complete the same total number of hours in the four-year course as students who come with entrance credits in other subjects.

The committee recognizes certain conventions in drawing. I do not think it would be wise to adopt these conventions. Manufacturing shops and drawing shops are not united in their use. In some drawing offices they use the first quadrant; in others, the third. It is probable that third quadrant drawing will eventually prevail, although first quadrant work was most generally used when I was a student. The same criticism applies to the recommendations regarding the direction in which lettering should be made to read. I do not think we could get manufacturers to adopt these conventions.

Professor E. F. Coddington: At the Ohio State University we recognize that high schools are giving valuable instruction in chemistry and physics. Our practice, in chemistry in particular, is to give two courses, one for those who have had chemistry in the high school and the other for those who have not. In one course, we give the students all that the average of the class can master. In the other course, we assume absolutely no knowledge of chemistry and obviously these students get less than the others. The instructors in chemistry find that there is not a great difference between the students in the two classes, but there is a perceptible difference.

In the college of engineering we require all students to have had high school physics, so that we have only one class in this subject. But in the college of arts the fact that some high schools do not teach physics is recognized and two courses are provided as in chemistry.

We should not be unduly exercised about this waste in teaching mathematics of which we have heard. I have found by experience that mathematics must be repeated again and again. I am teaching juniors, but I find frequently that I am teaching them high school mathematics. I do not consider this a wasted effort.

Professor W. A. Hedrick: I want to ask the members of the Society to manifest a spirit of coöperation in education. We have heard criticism of the mathematical knowledge of teachers of engineering on one hand, and now some members indicate by their remarks that they know little of the problems of secondary education. What we all need to do is to consider the subjects in which we are interested as education in a broad sense. We should use all the efforts we can in promoting the educational spirit among the secondary school teachers. I have been long associated with the secondary school teachers and I notice that they do not seem to have the same enthusiasm in their work as is manifested by the engineering school teachers.

In regard to the foreign languages and English, to which the president referred in his annual address, it should be remembered that we sometimes have to teach three foreign languages for college entrance. One foreign language should be sufficient to admit students to academic and engineering colleges; the secondary schools should not be compelled to teach three foreign languages for this purpose.

Professor Webb: It was not the intention of the committee to endeavor to dictate to the manufacturing interests of the country in the matter of conventions for the working drawings, but it seemed as if some conclusions could be reached by this society as to what should be the most desirable conventions which manufacturers would naturally accept. I think they would favor the conventions suggested. Meanwhile, if some of the educational institutions represented here prefer not to accept them, we cannot expect them to do so.

In the technical high schools, from which all the members of our committee come, we ask for recognition of subjects not heretofore recognized: but we are not particularly anxious to have engineering colleges require mechanical drawing for entrance, as that might turn away some students who come from secondary schools will not have drawing equipment for many years. We are giving this drawing in our schools, not for preparation for college, but because the people of the cities demand it.

It seems to me inconsistent that the college should raise the question as to whether a student should learn to hold a chisel in high school or in college, while such subjects as Vergil's Æneid and the writings of Poe are considered quite suitable for the high school.

There are two questions here: one as to what subjects should be acceptable for college entrance: and the second, how well they should be taught. These must be kept more or less separated in thought. We hope this Society will take action soon on the question of the recognition of our manual training and drawing as suitable high school subjects.

On the subject of physics, Professor Clifton of our committee, is at work investigating its status. His present opinion seems to be that there should be distinct high school courses and college courses in physics. It would be absurd to expect the high schools to give the student all of the physics he needs as an engineer, but it is equally absurd to think that we should not touch physics at all. In most instances the student should take high school physics, which is different from college physics. Many colleges will admit students who have not had high school physics or who are deficient in preparation in this branch. There would be no objection to requiring an examination of students who wished to offer physics for entrance, but it is discouraging for high school teachers to give them a year of high school physics, and then to have them told that their Latin and geometry are first-class, but the physics cannot be accepted. Physics of high school grade is certainly no more difficult than geometry.

REPORT OF COMMITTEE ON NECROLOGY.

JOHN GALBRAITH.

1846-1914.

John Galbraith, dean of the faculty of applied science and engineering, University of Toronto, was born in Montreal September 5, 1846. He received his early education at Port Hope, and in 1863 registered in arts at the University of Toronto. He graduated in 1868, receiving the degree of B.A. He was gold medallist in honor mathematics, and won the Prince of Wales prize for highest proficiency, established by the late King Edward VII during a visit to Canada.

When the school of practical science was changed in 1906 to the faculty of applied science and engineering of the University of Toronto, Dr. Galbraith was appointed dean of the faculty, which position he ably filled until the time of his death.

In 1907 when the engineering world was startled by the fall of the Quebec bridge, Dr. Galbraith was appointed a member of the commission of three to inquire into the disaster. Dr. Galbraith was a charter member of the Society for the Promotion of Engineering Education, serving for a number of years as a member of council, and in 1896–97 he was vice-president. He died Wednesday, July 22, 1914, at Go-Home Bay, Ontario.

CHARLES SIMEON DENISON.

1849-1913.

Professor Charles Simeon Denison was born at Gambier, Ohio, in 1849. He died July 31, 1913. When he was quite young the family moved to Lockport, N. Y., where he prepared for college. In 1868 he entered the University of Vermont, and there received the degrees of Bachelor of Science, Civil Engineer, Master of Science, and in 1907 his Alma Mater conferred the honorary degree of Doctor of Science upon him.

In 1872 he went to the University of Michigan as an instructor in engineering and drawing and was not yet twenty-three years of age when he became the real head of the department of drawing. He held that position until his death—forty-one years. Professor Ziwet, his colleague, speaks of him in the following terms:

''I have known Professor Denison somewhat more intimately only during the past fifteen years of his life. His long connection with the University and the part he had taken in establishing and developing the engineering courses had given him a very prominent position in the faculty of the engineering department. But his gentle, unassuming, and peace-loving nature kept him free from any appearance of undue self-assertion. In the faculty, as well as in the less formal discussions of the Standing Committee, his attitude was always one of conciliation. His loyalty to the engineering department and to the University as a whole was not prompted by personal ambition, but singly by that spirit of justice and fairmindedness which pervaded his whole nature.''

Professor Denison was a member of a great many societies but prominent among them is the Society for the Promotion of Engineering Education, of which Society he was a charter member. He took quite an interest in this Society, having written a paper on ''Drawing for Engineering Students,'' and which will be found in Volume 1 of the *Proceedings* of the Society.

JOSEPH EDWARD STUBBS.

1850–1914.

Joseph Edward Stubbs. D.D., LL.D., was born at Ashland, Ohio, March 19, 1850. and graduated from the Ashland High School in 1868. He entered the Ohio Wesleyan University at Delaware. O., in 1869. and in his sophomore year was made principal of the Delaware High School for the following term. For three years he held the position of tutor of Latin and Greek in the college department. to which he was elected by the faculty of the institution.

He graduated in 1873 from Ohio Wesleyan University, receiving the degree of Bachelor of Arts. The Master of Arts was conferred on him in 1876. From 1880 to 1886, Dr. Stubbs was city superintendent of schools at Ashland. In 1886 he was elected president of the Baldwin University at Berea, O. In 1892 he was granted a leave of absence of two years, and spent the time traveling in Europe studying German philosophy and literature in the University of Berlin. On his return, he was elected president of the College Association of Ohio and received the honorary degree of D.D. at German Wallace College in 1890.

He came to the University of Nevada as its president in 1895. in which capacity he was serving at the time of his sudden death. When Dr. Stubbs came to the University of Nevada, he found a faculty of eighteen persons and five buildings. Through his untiring efforts the faculty now numbers fifty and the buildings have increased to eighteen.

He was a member of the Society for the Promotion of Engineering Education for seventeen years.

FREDERICK WINSLOW TAYLOR.*

1856-1915.

Frederick Winslow Taylor, noted as the founder of the science of management, died suddenly of pneumonia on March 21, 1915. He was born in Germantown, Pa., in 1856. His eyesight became impaired in young manhood, necessitating his giving up his educational plans and he became an apprentice with William Sellers & Company. After learning the trades of patternmaker and machinist he entered the employ of the Midvale Steel Company and from a humble beginning in 1878 became chief engineer in 1884. While here he studied at night and received the degree M.E. in 1883 from the Stevens Institute of Technology. He also began the systematic study of problems relating to the output of tools and men which later became his life work.

After three years as manager of a company operating large paper mills in Maine he took up consulting practice, as part of which he accomplished remarkable results for the Bethlehem Steel Company, inventing, with Maunsel White a process of heat treating steel for cutting tools.

Having by this time acquired a competence. for the balance of his life he devoted his energy and experience to the cause of industrial progress without compensation. He was a devoted members of the A. S. M. E. serving terms as vice-president and president and was of recent years an interested member of this Society, contributing to its proceedings a valuable and effective paper on "Why Manufacturers Dislike College Students," Vol. XVII, page 79. His personality was remarkable and those who knew him best prized him even more as a man than as an engineer. His success with young men was due to the fact that, while an uncompromising taskmaster, he recognized the value of time as an element in training, and was able to overlook the frequent personal issues which those who did not understand his methods insisted in raising at every turn.

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* This sketch was based upon an appreciative article appearing in the A. S. M. E. Journal, April, 1915, page 9.

CHARLES LABAN ADAMS.

1856-1914.

Charles Laban Adams was born November 26, 1856, in New York City. His early education was in the public schools, and later in the Massachusetts Normal Art School. He also studied painting at the Art Museum and with A. Oudinot, a French landscape painter and pupil of Corot. He kept up his interest in painting, and exhibited at the Art Clubs in New York, Philadelphia and Boston. He was a member of the Boston Art Club and the Technology Clubs of Boston and New York. For many years in addition to his teaching at the institute he was superintendent of the Roxbury Free Evening Drawing School.

Professor Adams had been a teacher of drawing at the Massachusetts Institute of Technology since 1881. In 1881–82 he took a special course, in his spare time, in the Mechanical Engineering Department. This work associated him with the class of 1884, M. I. T. In 1885 he developed a course in lettering and a course in freehand drawing for the architectural department, the latter course including the study of the human figure as a part of decorative design. In 1903 he was appointed assistant professor of drawing and descriptive geometry. In 1904 he was appointed associate professor: and in 1912 professor of drawing and descriptive geometry.

The books published by Professor Adams are as follows: "Letter Drawing Plates," published in 1893. In 1905 he published a book on "Mechanical Drawing, Technique and Working Methods for Technical Students." In 1907 he published "Notes on Descriptive Geometry."

He became a member of this Society in 1904.

In June, 1914, while on a tour through Europe he had an attack of appendicitis. An unsuccessful operation was performed at Boerhaave Kliniek in Amsterdam where he died September 16.

SAMUEL BENEDICT CHRISTY.

1853-1914.

Professor S. B. Christy was born in San Francisco in 1853. He died on November 30, 1914, after nearly thirty years of service as professor of mining and metallurgy in his alma mater.

In *Engineering & Mining Journal,* December 19, 1914, page 1105, Dr. R. W. Raymond writes as follows: "A man so intensely and continuously active in so many directions leaves 'footprints on the sands of time' too numerous to be traced and interpreted by a hurried reporter. I know that he discussed in 1891 the practice of chlorination at the Alaska-Treadwell mine; that he was engaged for a series of years in the U. S. Circuit Court as an expert in the metallurgy of quicksilver and of lead; and that in 1900, as the result of patient and thorough experiment, he patented an improved process for the recovery of gold and silver from dilute cyanide solutions. And I know that to the *Transactions* of the American Institute of Mining Engineers (of which he became a member in 1883, and was a vice-president in 1891 and 1892) he contributed a series of highly original and important papers on the metallurgy of gold, silver and mercury, and on the training of mining engineers and the relation of American mining schools to the mining industry, as well as a remarkable biographical notice of Joseph Le Conte, his friend and colleague, which has been recognized as the most appreciative and satisfactory of the tributes paid to that illustrious and beloved leader and teacher. But beyond this list, which is enough of itself to secure for Professor Christy a permanent place in the history of American scientific and technical progress, there remains his work in connection with the California Academy of Sciences (of which he was a life member and for five years corresponding secretary), the Society for the Promotion of Engineering Education (of which he was a charter member and for three years vice-president), the California Miners' Association and other bodies."

FRANK OLIN MARVIN.

1852-1915.

After several years of ill health, Dean Frank O. Marvin, of the University of Kansas, died February 6, in San Diego, California. He and Mrs. Marvin had gone to California a month previous in the hope of improvement for the dean's health. The funeral services were held in the Congregational church at Lawrence, February 11.

Dean Marvin was born in Alfred, New York, May 27, 1852. He was a graduate of Allegheny College. holding the degrees of Civil Engineer and Master of Arts. He secured practical work in the field in railway, irrigation, sanitary and municipal engineering. This furnished a basis for his later teaching work. He became a teacher in the university in 1875, but left the following year to become principal of the Lawrence High School. He returned to the university in 1877 as assistant in mathematics and physics. In 1883 he became professor of engineering, and dean of the school of engineering in 1891. Two years ago, he gave up the active direction of the school, receiving the title of advisory dean.

Professor Marvin's life work was the establishment and building up of the school of engineering. He came to this work in the late seventies a young man, with a good professional training, some experience in active railroad work and a very marked ability to meet young men and boys in such a manner as to win their confidence and admiration. It would seem that his qualifications for the work were ideal. He was an active and loyal member of the American Society of Civil Engineers and of all the Kansas societies for scientific research. He was one of the founders of, and was always very active in the Society for the Promotion of Engineering Education, serving as president in 1900–01, and was an active member and past president of the Society of Sigma XI.

WILLIAM F. GURLEY.

1860-1915.

William F. Gurley was born in Troy, N. Y., June 11, 1860, and received his early training in that city. Upon his graduation from Williams College in 1882, he entered the factory of W. and L. E. Gurley, where he acquired a thorough and practical knowledge of the manufacturing of civil engineers' and surveyors' instruments in the business founded by the two brothers, William Gurley, his uncle, and Lewis E. Gurley, his father.

At his father's death he succeeded to the management of the business, and when the company was incorporated in 1900 he became its president, a position which he held until his death.

Mr. Gurley was greatly interested in educational matters, being a school commissioner of the city of Troy, a trustee of the Rensselaer Polytechnic Institute, and of Colgate University, and president of the Emma Willard School of Troy, the oldest institution in America devoted to the higher education of women. The four magnificent new buildings of the latter school, made possible by Mrs. Sage's $1,000,000 gift, were planned and built under Mr. Gurley's direction. He was president of the Union National Bank, treasurer of the Taylor Electric Truck Company, and The Troy *Record*, besides being prominently identified with practically every charitable and philanthropic institution in Troy. For the last two years he has been a member of the Society for the Promotion of Engineering Education, and has always taken an interest in its affairs. Mr. Gurley's death came unexpectedly at Atlantic City on February 17, 1915.

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